



Geometry Optimization Study of the Side-Coupled Structure Using SUPERFISH

Ping zhou

February 27, 1989

This investigation uses SUPERFISH to calculate the effective shunt impedance, ZT^2 , ratio of peak surface electric field to average electric field on the axis, E_{peak}/E_0 and transit time factor, T for certain variations of the reference design geometry for the side-coupled structure (SCS) cavity (Figure 1). The Fermilab Linac Upgrade will use side-coupled cavities from 116 to 400 Mev. Calculations were done at eight selected energies in this range.

SUPERFISH is an axisymmetric code. Because of the existence of coupling slot in the actual cavity, the frequencies used in the SUPERFISH calculation (offset frequencies) for cavities at various energies are higher than the actual operational frequency (805 MHz). These frequencies were provided by Tom Jurgens, and are listed in Table 1.

The shunt impedance ZT^2 is relatively sensitive to the cavity radius, web thickness and bore radius. Each of these three dimensions was varied separately while holding all other dimensions equal to the original reference design (Fermilab Linac Conceptual Design Report (Revision 2)) values. The frequency change caused by varying the cavity dimensions is compensated by moving the nose cone in and out (i.e. by changing the gap separation). The results for ZT^2 , E_{peak}/E_0 and T are collected in Table 2, 3 and 4, respectively at eight different energies. The results are also shown graphically in Appendices 1, 2 and 3. Listed in Table 5 are ZT^2 , E_{peak}/E_0 and T for a new SCS cavity design which has a cavity radius of 13.455 cm and web thickness of 0.75 cm. Other dimensions for the New Design are the same as in the original reference design. This design results in about 3% to 12% higher ZT^2 at different beta than the reference design, and corresponds to about 12% to 8% higher E_{peak}/E_0 respectively.

From these results one can extract plots for the variation of ZT^2 , E_{peak} and T as a function of the relativistic beta (v/c). Four SCS designs are presented together in the overview following Table 4. The first is the SCS Reference Design with ZT^2 , E_{peak} and T vs. beta plotted. The values differ slightly from those of the original reference design because of the frequency offsets used here (Table 1). The SCS geometry used in the Design Report was developed at 805 MHz.

The Optimized Design is the one in which ZT^2 is maximized by adjusting the cavity radius. The price paid for maximum ZT^2 is an increase in the peak fields compared to the Reference Design. The third is the SCS Adjusted Design in which the cavity radius is changed to 13.728 cm so that the peak fields are about equal to those in the Linac Conceptual Design Report. The shunt impedance vs. beta turns out to be approximately 1% larger than that in the Design Report, mainly due to the fact that the cavity is designed for the new offset frequency (~ 820 MHz) rather than 805 MHz. The shunt impedance for the New Design is larger than the Optimized Design for almost all the beta values used here, and the difference is mostly attributed to the thinner web used in the New Design.

SCS Reference Design Cavity

(dimensions in mm)

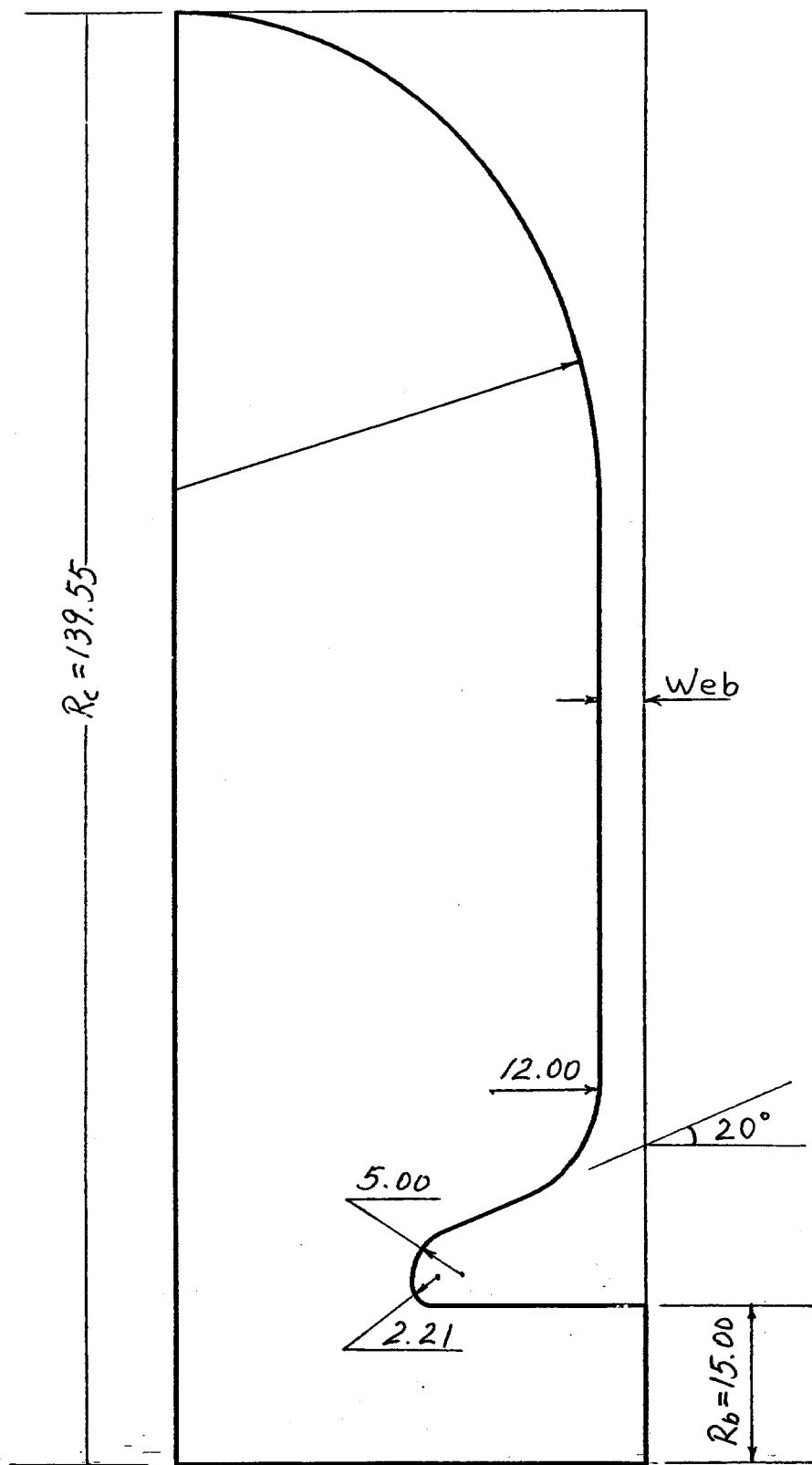


Figure 1.

Table 1.

Offset frequencies used in SUPERFISH calculations
at the eight different energies used in the study

energy(Mev)	beta	offset freq.	cell length(cm)
116.540	0.4570	820.866	4.2544
137.900	0.4898	820.155	4.5603
165.100	0.5262	819.370	4.8995
203.400	0.5698	819.060	5.3048
243.500	0.6080	818.509	5.6610
285.100	0.6418	818.596	5.9750
338.700	0.6784	818.378	6.3159
393.900	0.7099	818.032	6.6098

Table 2.

ZTT(Mohm/m) for Variations of the Reference Design SCS Cavity
 (Asterisk denotes Reference Design values)

Energy (Mev)	116.54	137.9	165.1	203.4	243.5	285.1	338.7	393.9
Beta	0.4570	0.4898	0.5262	0.5698	0.6080	0.6418	0.6784	0.7099
<hr/>								
Radius (cm) (Rc)								
11.955	41.99	44.22	46.25	48.14	49.37	50.19	50.79	51.09
12.455	42.94	45.41	47.63	49.84	51.32	52.35	53.14	53.61
12.955	42.88	45.51	48.03	50.53	52.30	53.56	54.63	55.31
13.455	41.56	44.37	47.13	49.93	51.97	53.51	54.83	55.77
* 13.955	38.33	41.30	44.32	47.42	49.83	51.62	53.32	54.60
14.255	35.04							
14.455		35.23	38.53	42.10	44.94	47.11	49.24	50.93
Web (mm)								
1.0	42.83	45.52	48.19	50.89	52.93	54.44	55.83	56.81
3.0	40.64	43.47	46.32	49.25	51.46	53.10	54.64	55.75
* 5.0	38.33	41.30	44.32	47.42	49.83	51.62	53.32	54.60
7.0	35.82	38.95	42.08	45.41	47.94	49.90	51.79	53.19
Bore Radius (cm) (Rb)								
* 1.50	38.33	41.30	44.32	47.42	49.83	51.62	53.32	54.60
1.70	36.00							
2.00	32.98	35.66	38.39	41.30	43.59	45.35	47.03	48.29
2.50	28.98	31.34	33.78	36.44	38.53	40.17	41.76	42.98
3.00	26.06	28.12	30.26	32.62	34.50	35.99	37.46	38.57

Table 3.

Epeak/E0 for variations of the Reference Design SCS Cavity
 (Asterisk denotes Reference Design values)

Energy (Mev)	116.54	137.9	165.1	203.4	243.5	285.1	338.7	393.9
Beta	0.4570	0.4898	0.5262	0.5698	0.6080	0.6418	0.6784	0.7099
<hr/>								
Radius (cm) (Rc)								
11.955	6.696	6.658	6.647	6.584	6.537	6.513	6.554	6.539
12.455	6.043	6.017	6.018	6.002	5.979	5.984	6.093	6.069
12.955	5.400	5.417	5.446	5.475	5.532	5.541	5.544	5.596
13.455	4.746	4.785	4.840	4.932	5.019	5.042	5.089	5.197
* 13.955	4.071	4.146	4.242	4.365	4.461	4.541	4.648	4.685
14.255	3.598							
14.455		3.372	3.529	3.703	3.839	3.928	4.055	4.125
Web (mm)								
1.0	3.803	3.901	3.988	4.130	4.267	4.319	4.408	4.481
3.0	3.941	4.045	4.147	4.241	4.313	4.411	4.474	4.569
* 5.0	4.071	4.146	4.242	4.365	4.461	4.541	4.648	4.685
7.0	4.229	4.315	4.412	4.485	4.531	4.650	4.680	4.765
B-Radius (cm) (Rb)								
* 1.50	4.071	4.146	4.242	4.365	4.461	4.541	4.648	4.685
1.70	3.994							
2.00	3.912	3.937	4.051	4.160	4.236	4.292	4.353	4.457
2.50	3.733	3.823	3.897	3.998	4.056	4.143	4.178	4.257
3.00	3.651	3.713	3.783	3.867	3.967	4.018	4.070	4.116

Table 4.

Transit Time Factor for variations of the Reference Design SCS Cavity
 (Asterisk denotes Reference Design values)

Energy (Mev)	116.54	137.9	165.1	203.4	243.5	285.1	338.7	393.9
Beta	0.4570	0.4898	0.5262	0.5698	0.6080	0.6418	0.6784	0.7099
Radius (cm) (Rc)								
11.955	0.896	0.902	0.907	0.911	0.914	0.916	0.917	0.918
12.455	0.886	0.891	0.896	0.900	0.902	0.904	0.905	0.905
12.955	0.872	0.877	0.882	0.885	0.887	0.888	0.889	0.889
13.455	0.851	0.857	0.861	0.865	0.867	0.868	0.869	0.869
* 13.955	0.819	0.825	0.831	0.835	0.839	0.840	0.842	0.843
14.255	0.788							
14.455		0.770	0.780	0.789	0.795	0.799	0.802	0.805
Web (mm)								
1.0	0.796	0.803	0.809	0.815	0.819	0.821	0.823	0.825
3.0	0.807	0.814	0.820	0.825	0.829	0.831	0.833	0.834
* 5.0	0.819	0.825	0.831	0.835	0.839	0.840	0.842	0.843
7.0	0.829	0.835	0.840	0.844	0.847	0.848	0.850	0.851
B-Radius (cm) (Rb)								
* 1.50	0.819	0.825	0.831	0.835	0.839	0.840	0.842	0.843
1.70	0.799							
2.00	0.772	0.781	0.788	0.795	0.800	0.804	0.807	0.810
2.50	0.736	0.744	0.752	0.761	0.767	0.772	0.777	0.781
3.00	0.708	0.716	0.724	0.733	0.740	0.745	0.751	0.755

Table 5.

ZTT, Epeak and Transit Time Factor for New SCS Cavity Design
(Cavity radius of 13.455cm and web thickness of 0.75cm)

Energy (Mev)	116.54	137.9	165.1	203.4	243.5	285.1	338.7	393.9
Beta	0.4570	0.4898	0.5262	0.5698	0.6080	0.6418	0.6784	0.7099
ZTT (Mohm/m)	43.21	45.91	48.54	51.18	53.09	54.49	55.73	56.56
Epeak/EO	4.625	4.663	4.726	4.825	4.898	4.967	5.007	5.081
T	0.846	0.851	0.856	0.859	0.862	0.863	0.865	0.865

Overview of Designs

ZT^2 , E_{peak} and T vs. Beta for the Reference Design, the Optimized¹, Adjusted² and New³ SCS Design

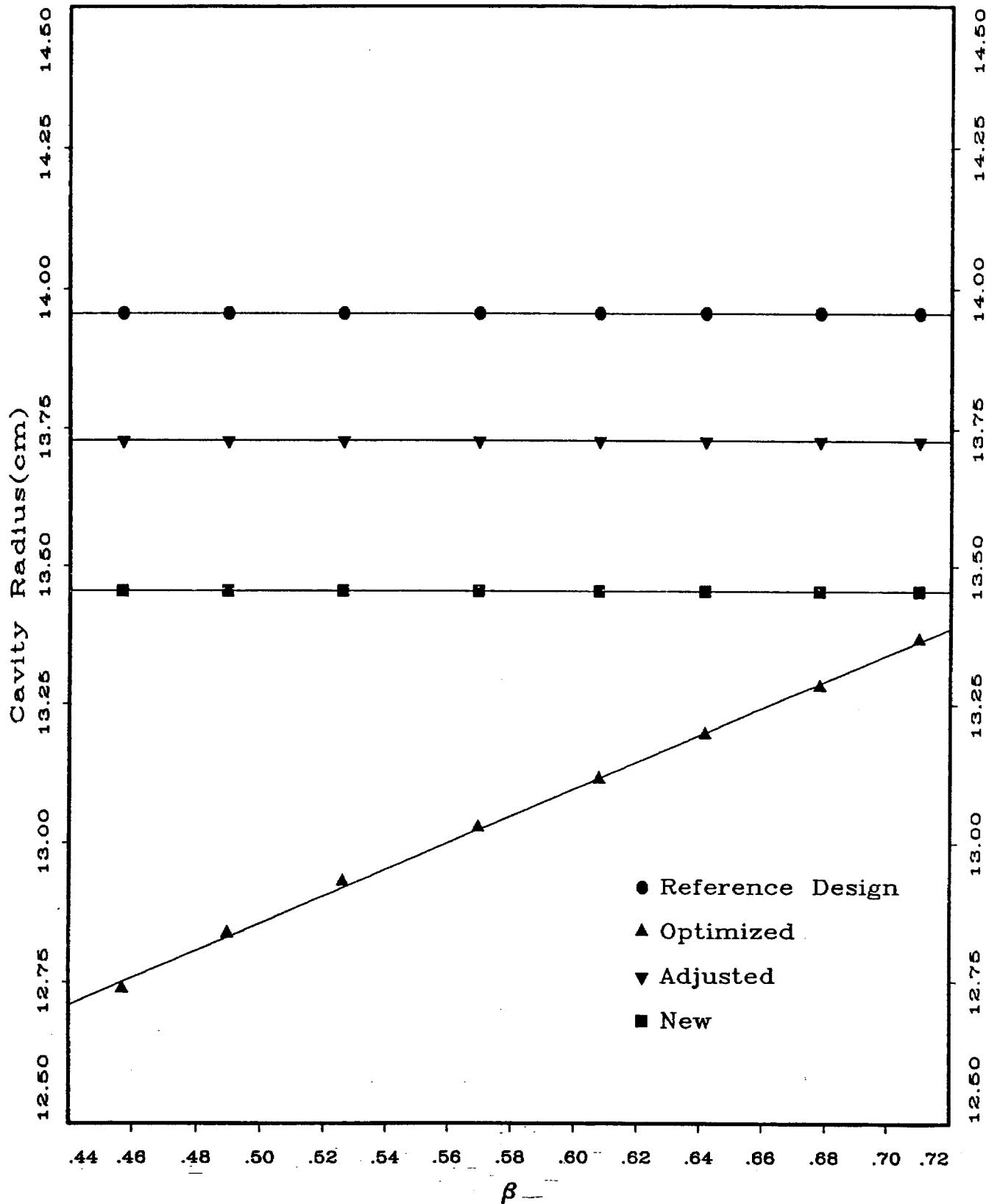
1 : ZT^2 maximized with respect to cavity radius

2 : E_{peak} equal to that in the Linac Conceptual Design Report (Revision 2)

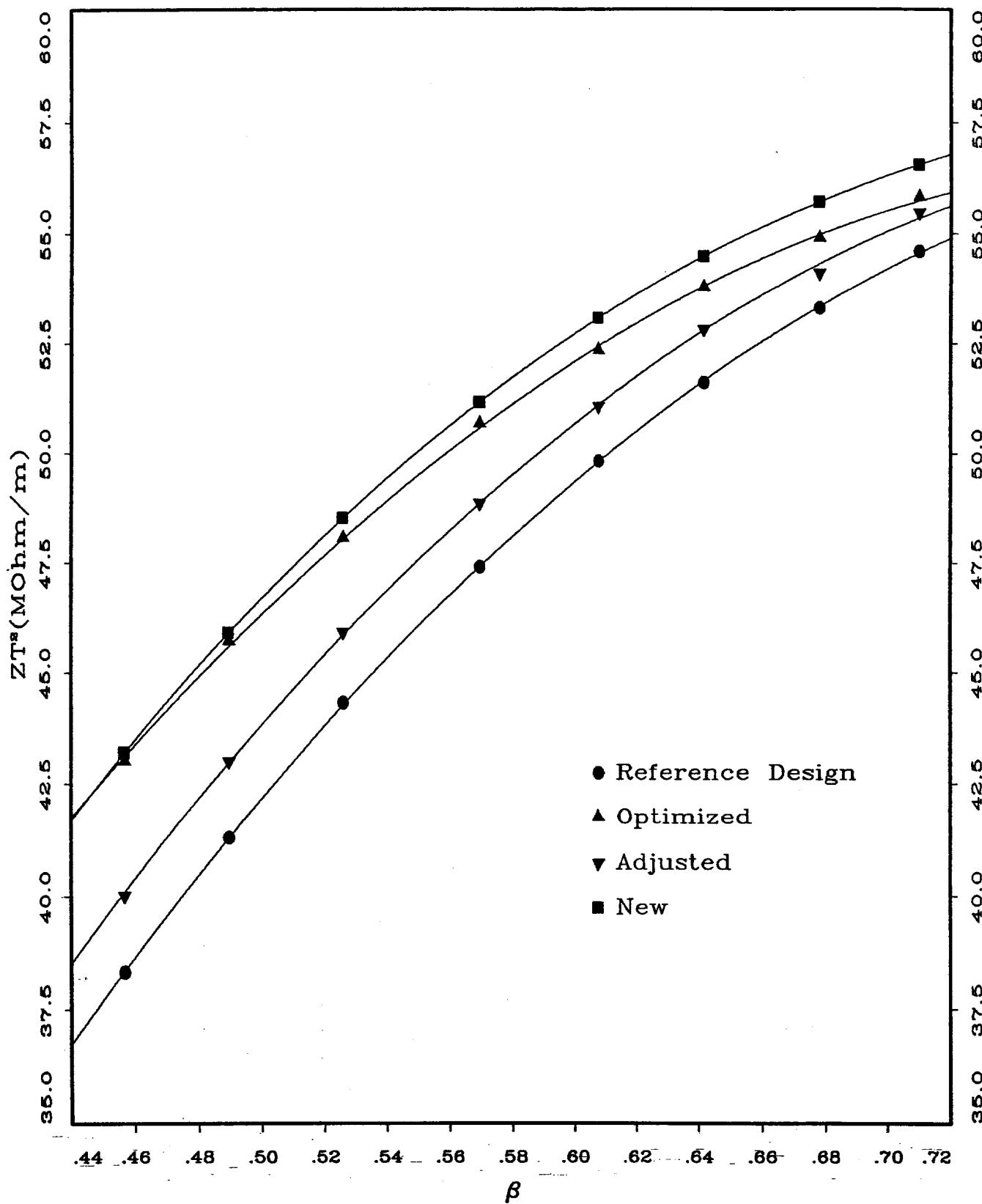
Cavity radius = 13.728 cm

3 : With cavity radius of 13.455 cm and web thickness of .75 cm

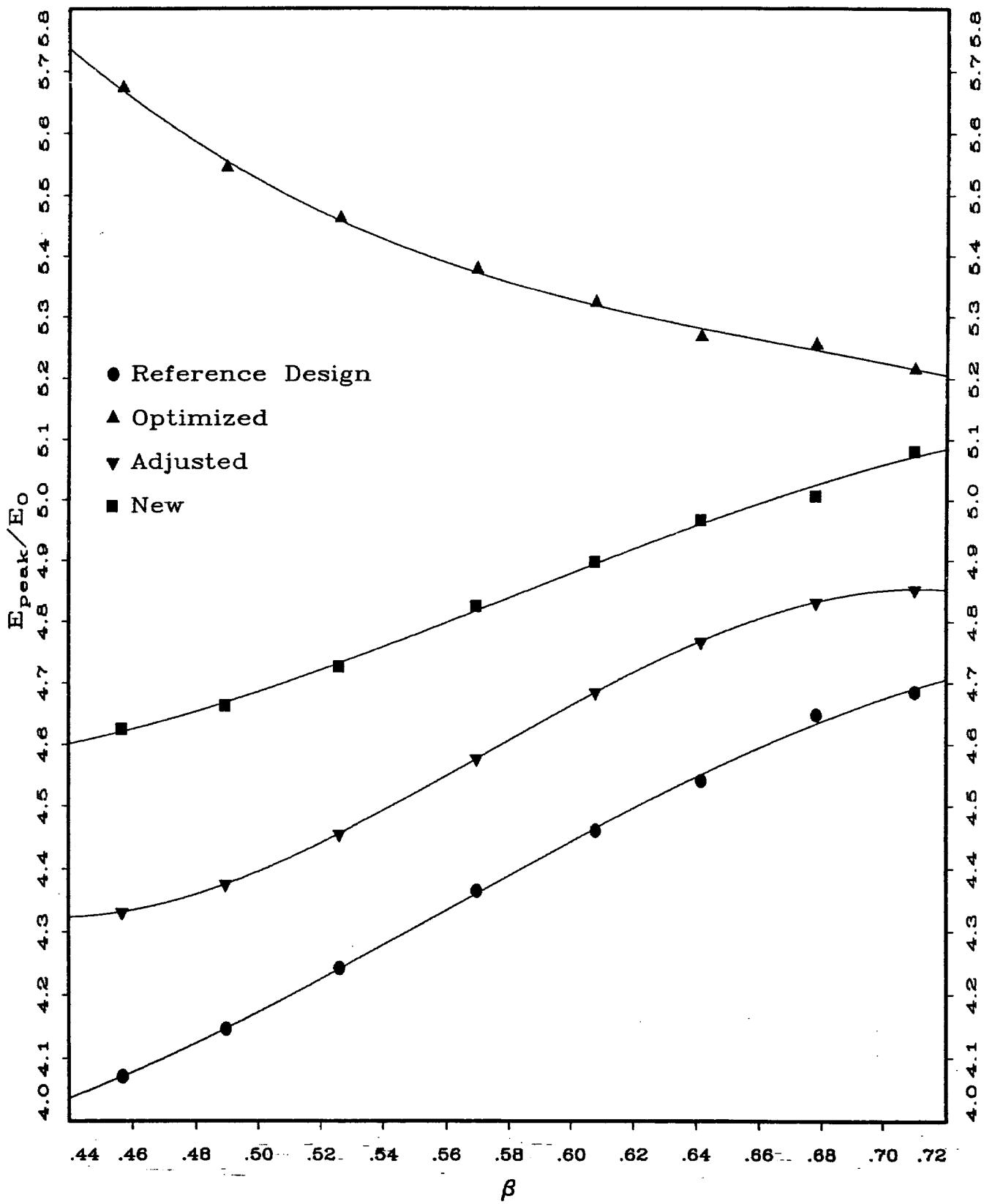
Cavity Radius vs. Beta for Various Designs



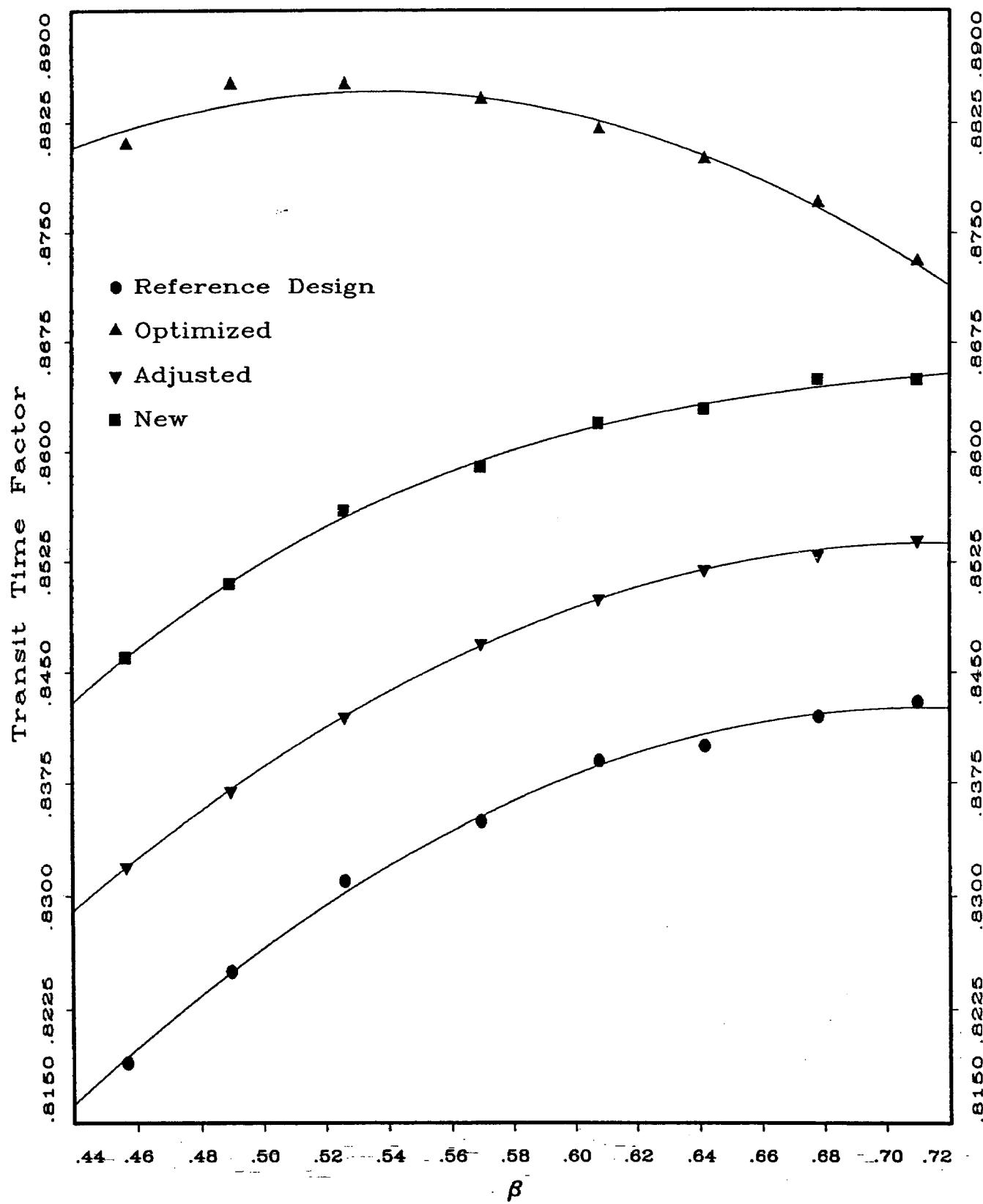
ZT² vs. Beta for Various Designs



E_{peak}/E_0 vs. Beta for Various Designs



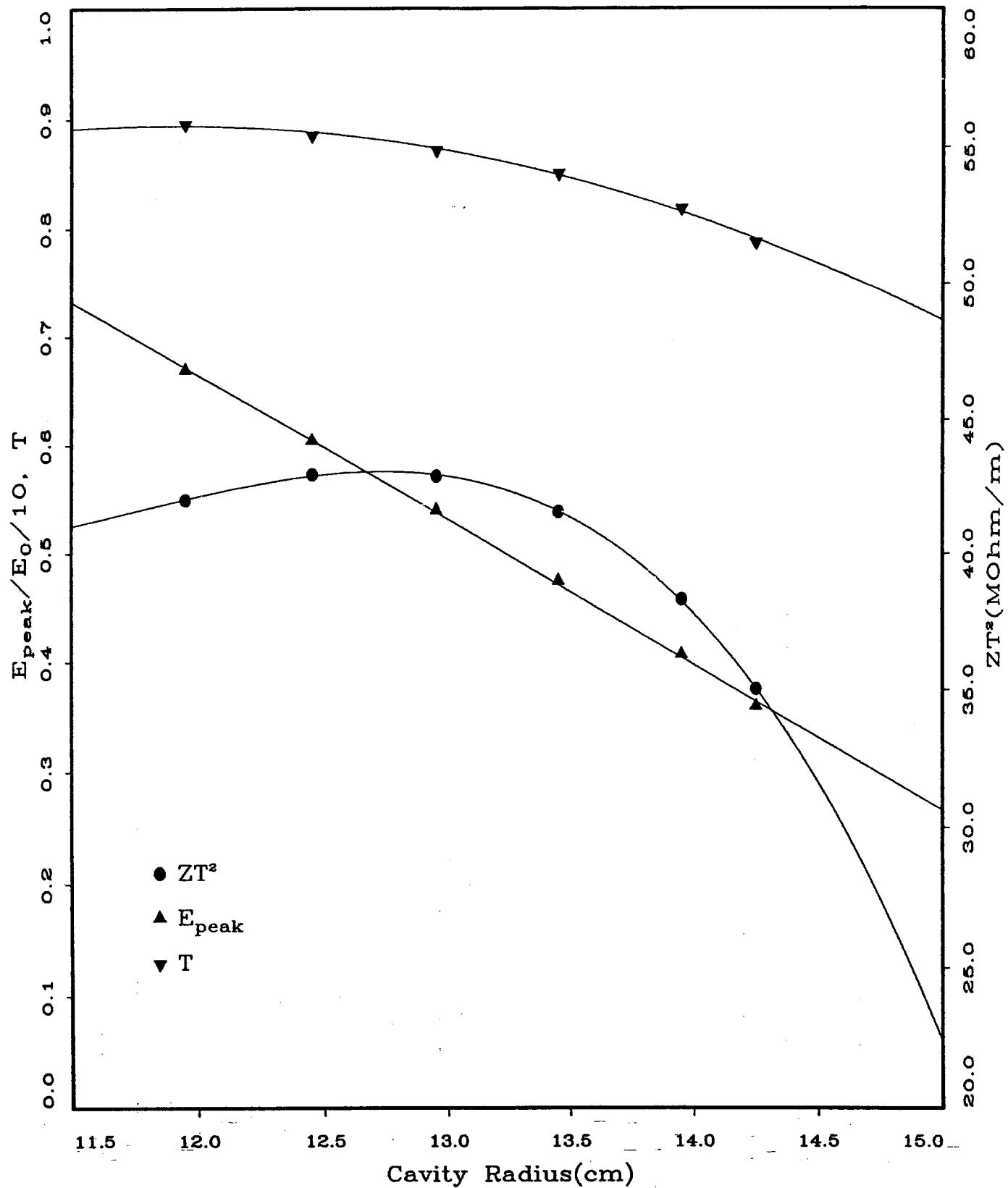
T vs. Beta for Various Designs



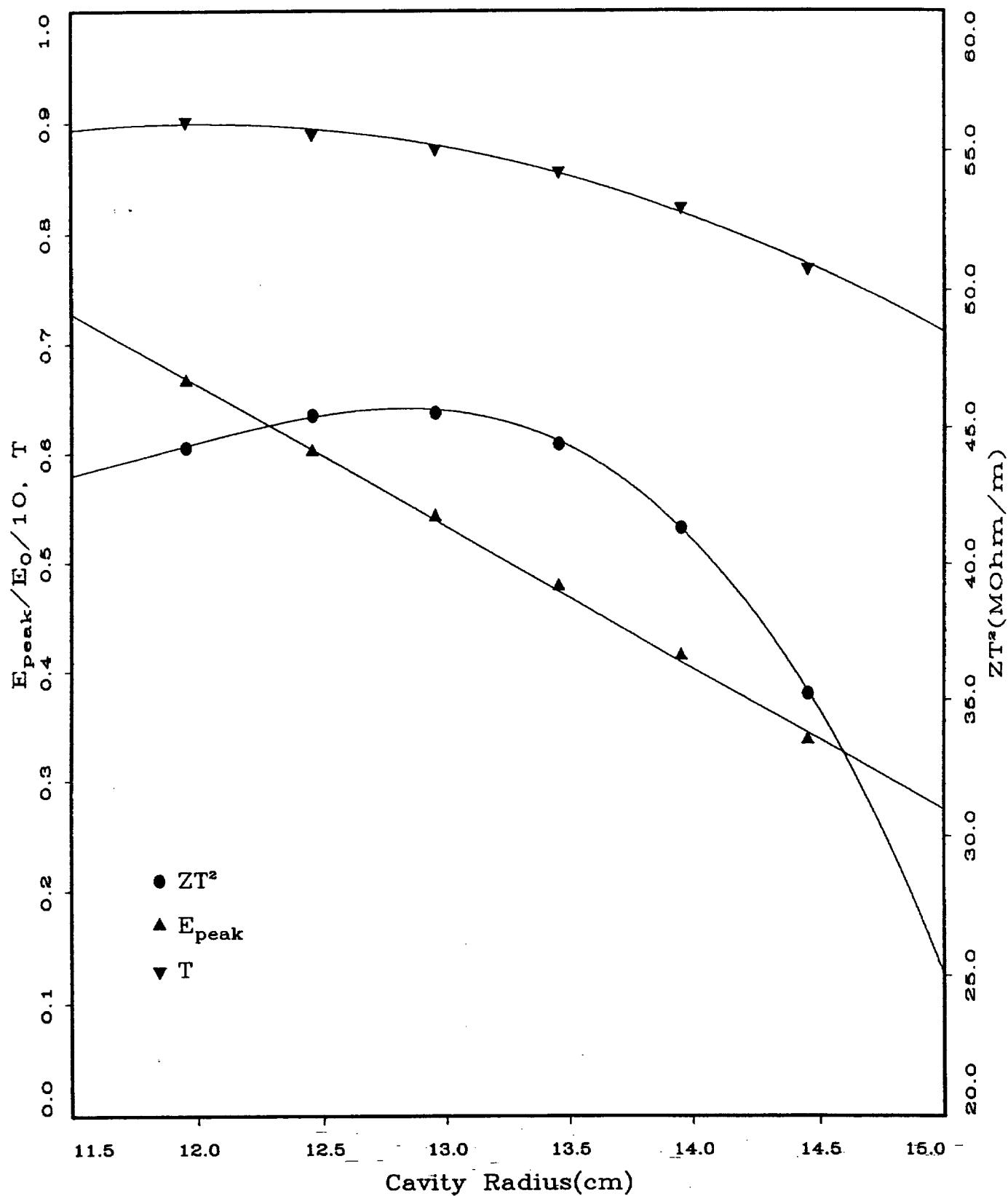
Appendix 1

ZT^2 , E_{peak} and T vs. Cavity Radius at the eight energies listed in Table 1. All other cavity dimensions are the same as the Reference Design.

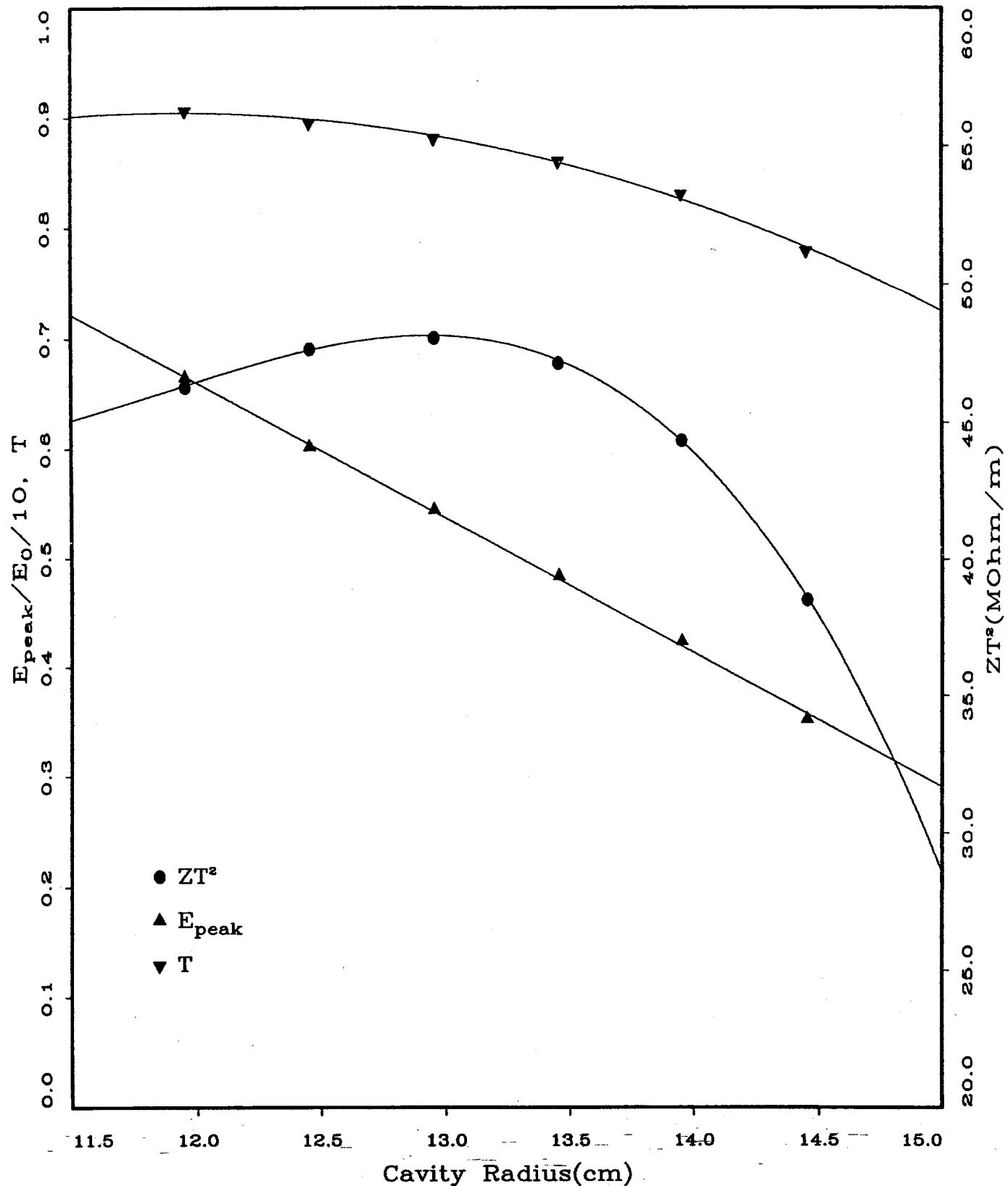
ZT^2 , E_{peak} and T vs. Radius at 116.54Mev



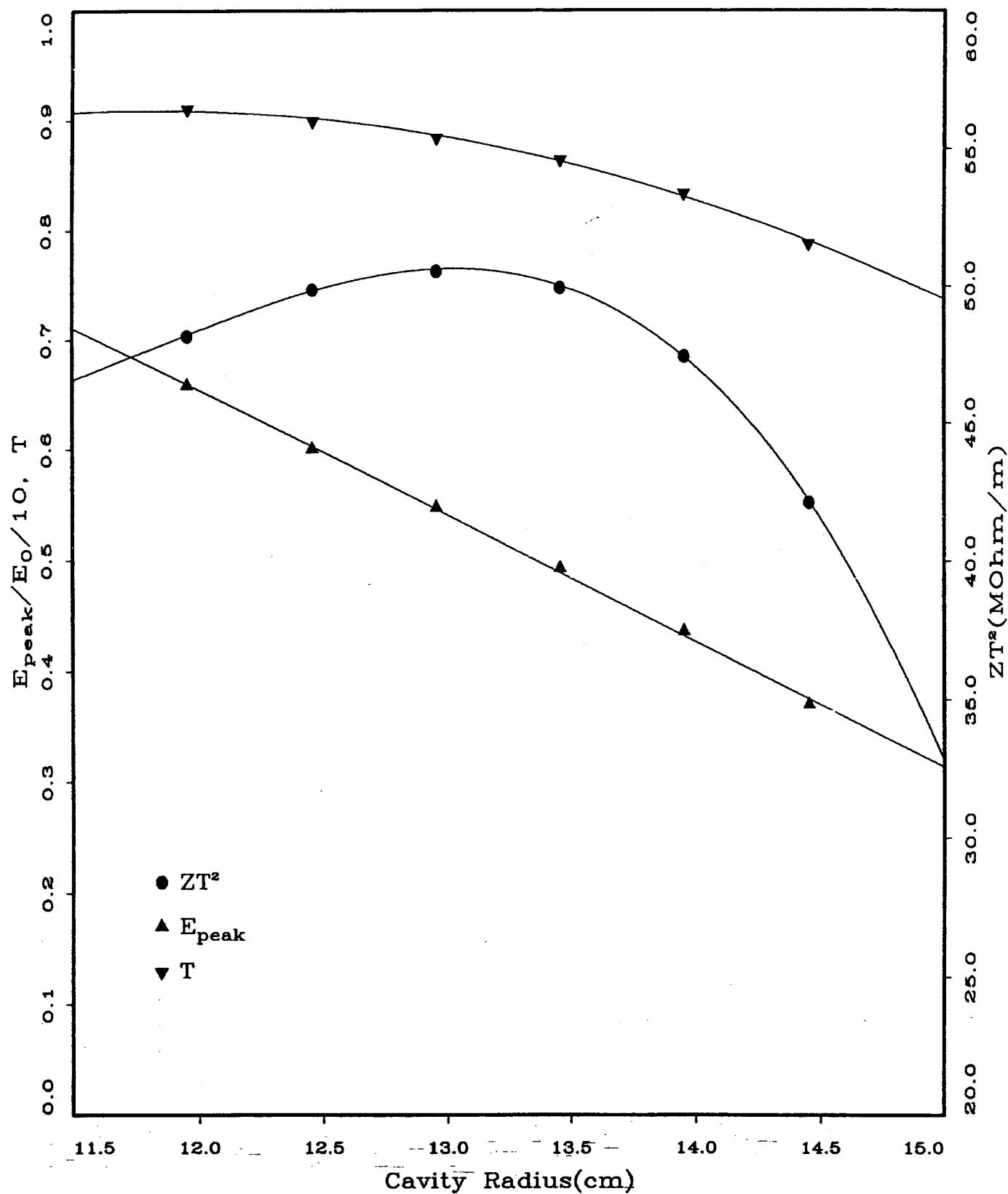
ZT^2 , E_{peak} and T vs. Radius at 137.9Mev



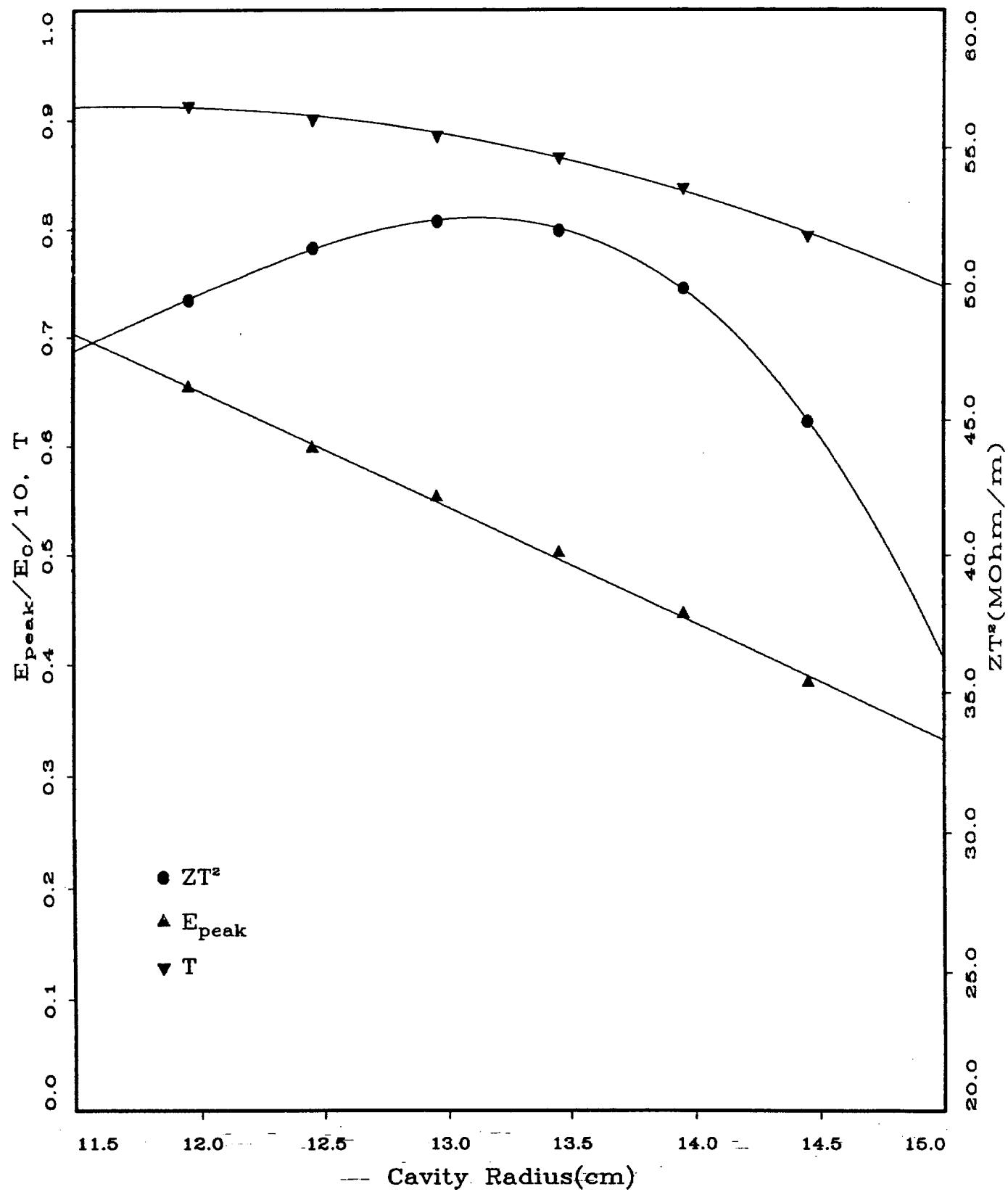
ZT^2 , E_{peak} and T vs. Radius at 165.1 Mev



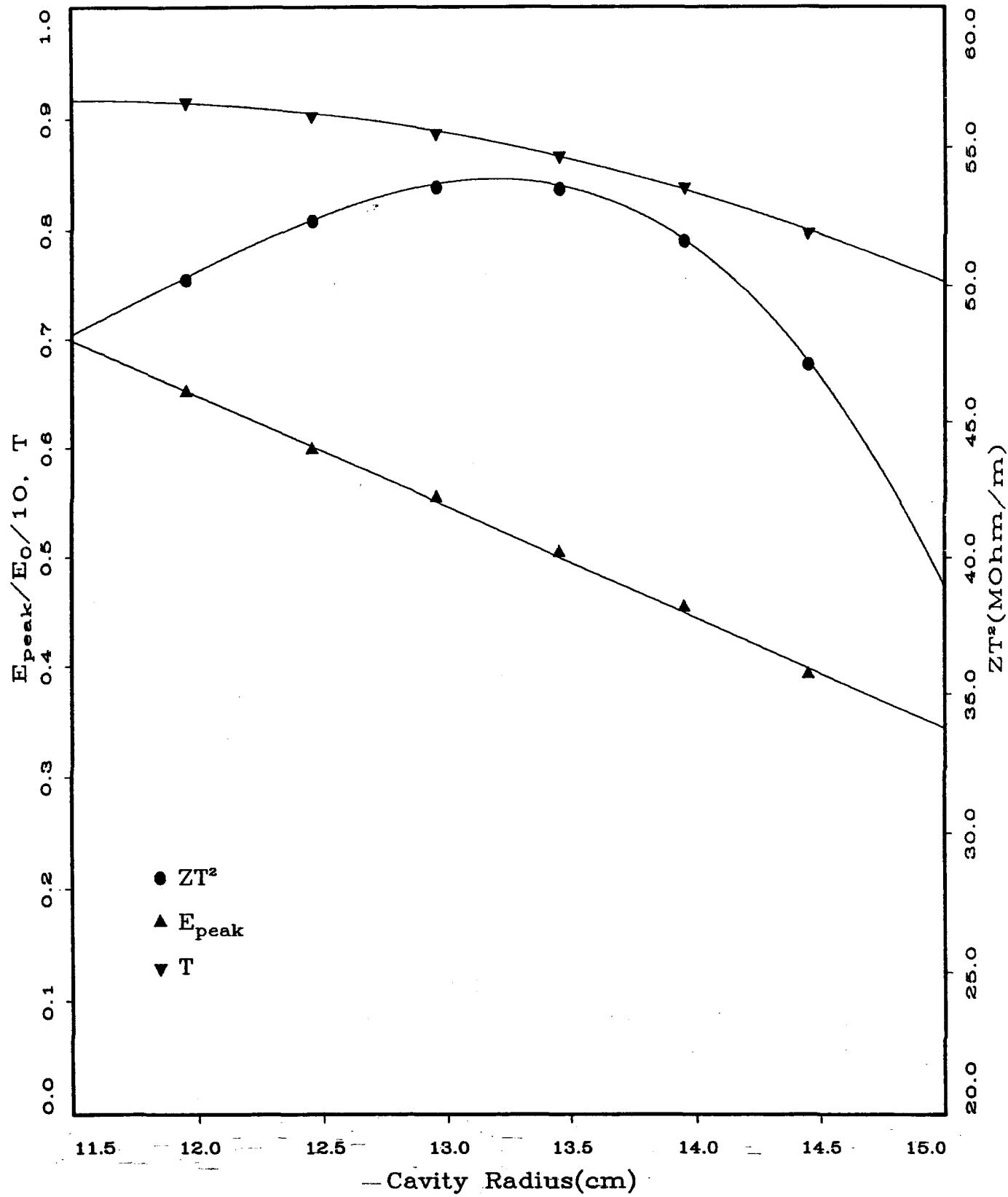
ZT^2 , E_{peak} and T vs. Radius at 203.4Mev



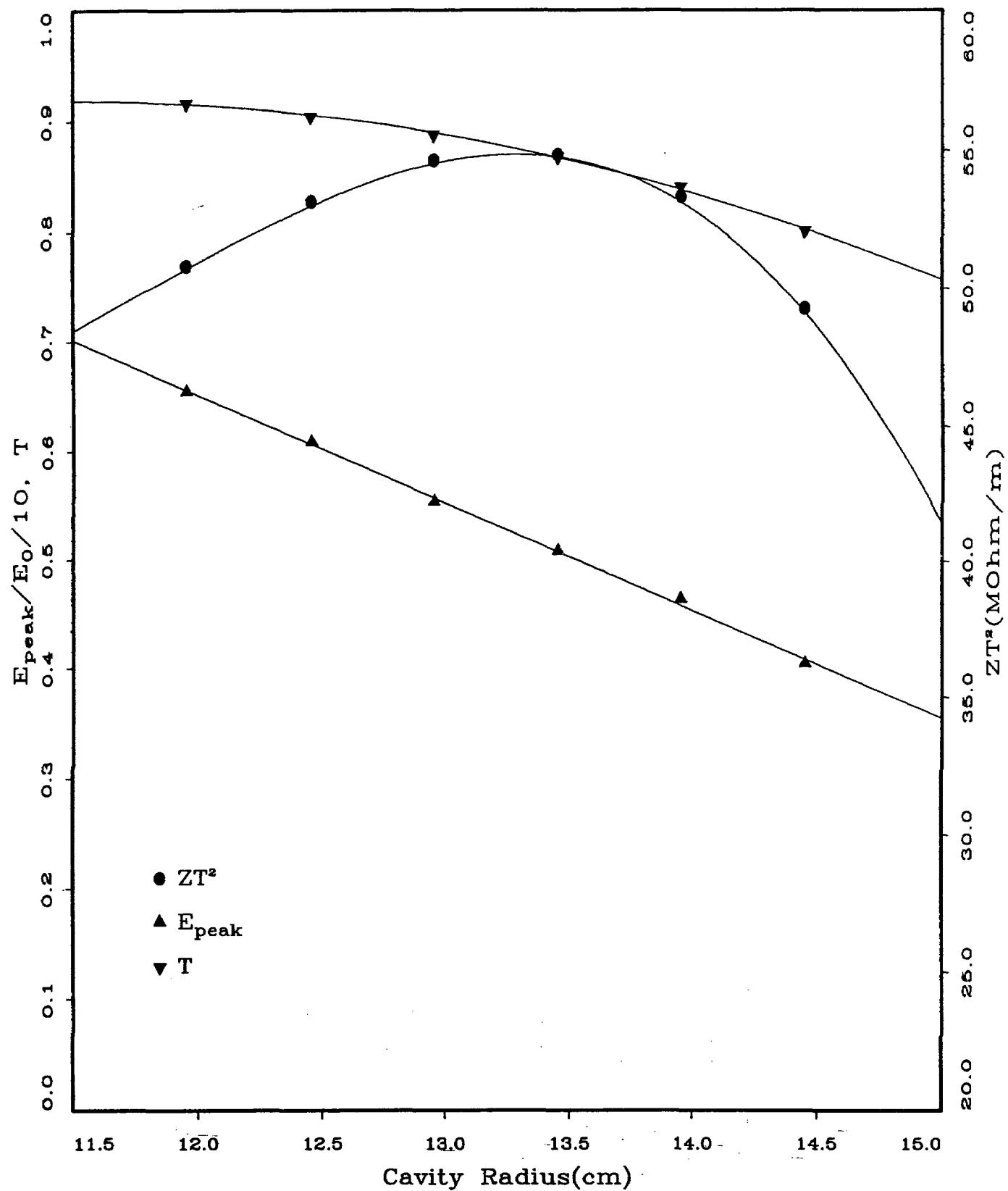
ZT^2 , E_{peak} and T vs. Radius at 243.5Mev



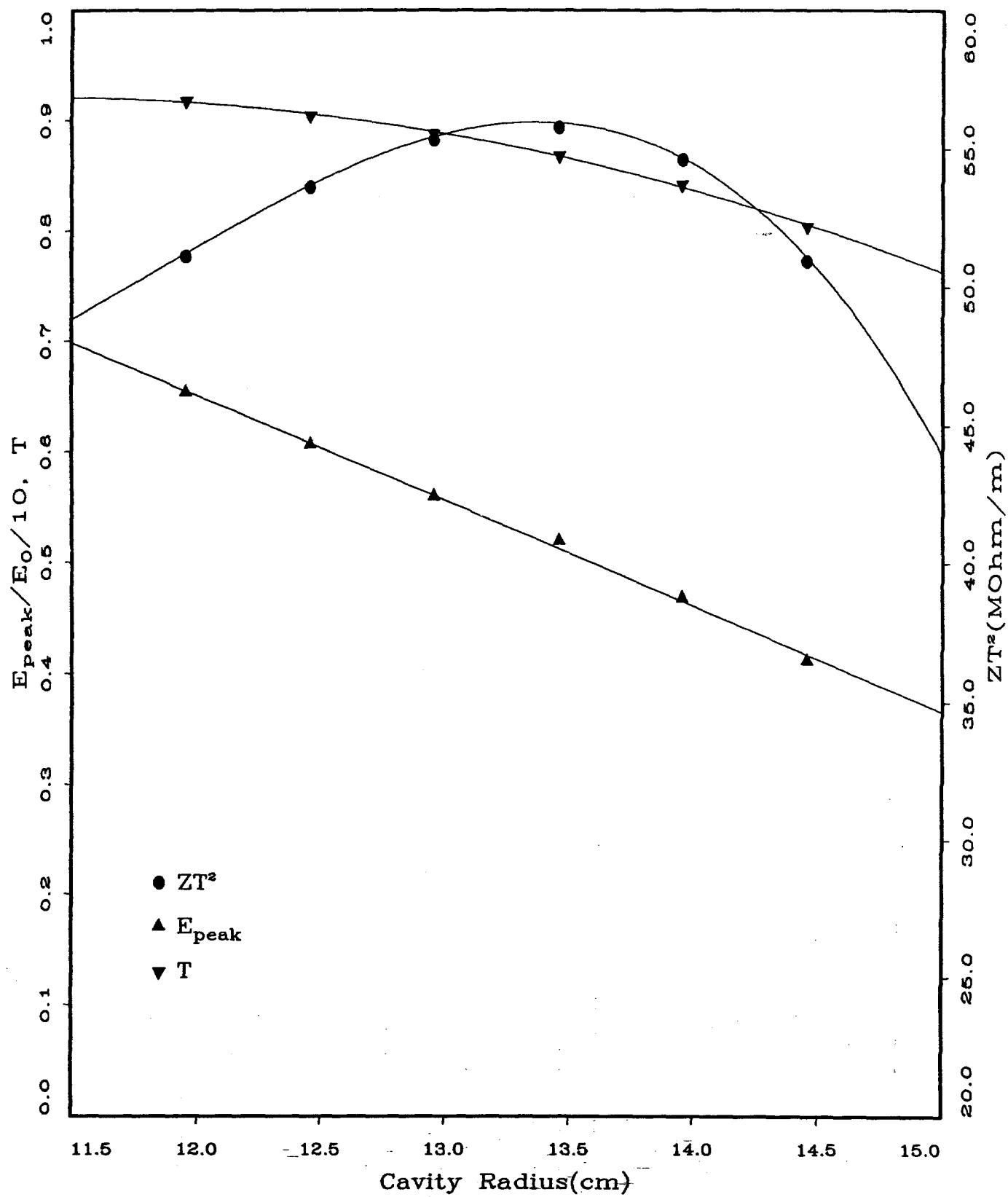
ZT^2 , E_{peak} and T vs. Radius at 285.1Mev



ZT^2 , E_{peak} and T vs. Radius at 338.7Mev



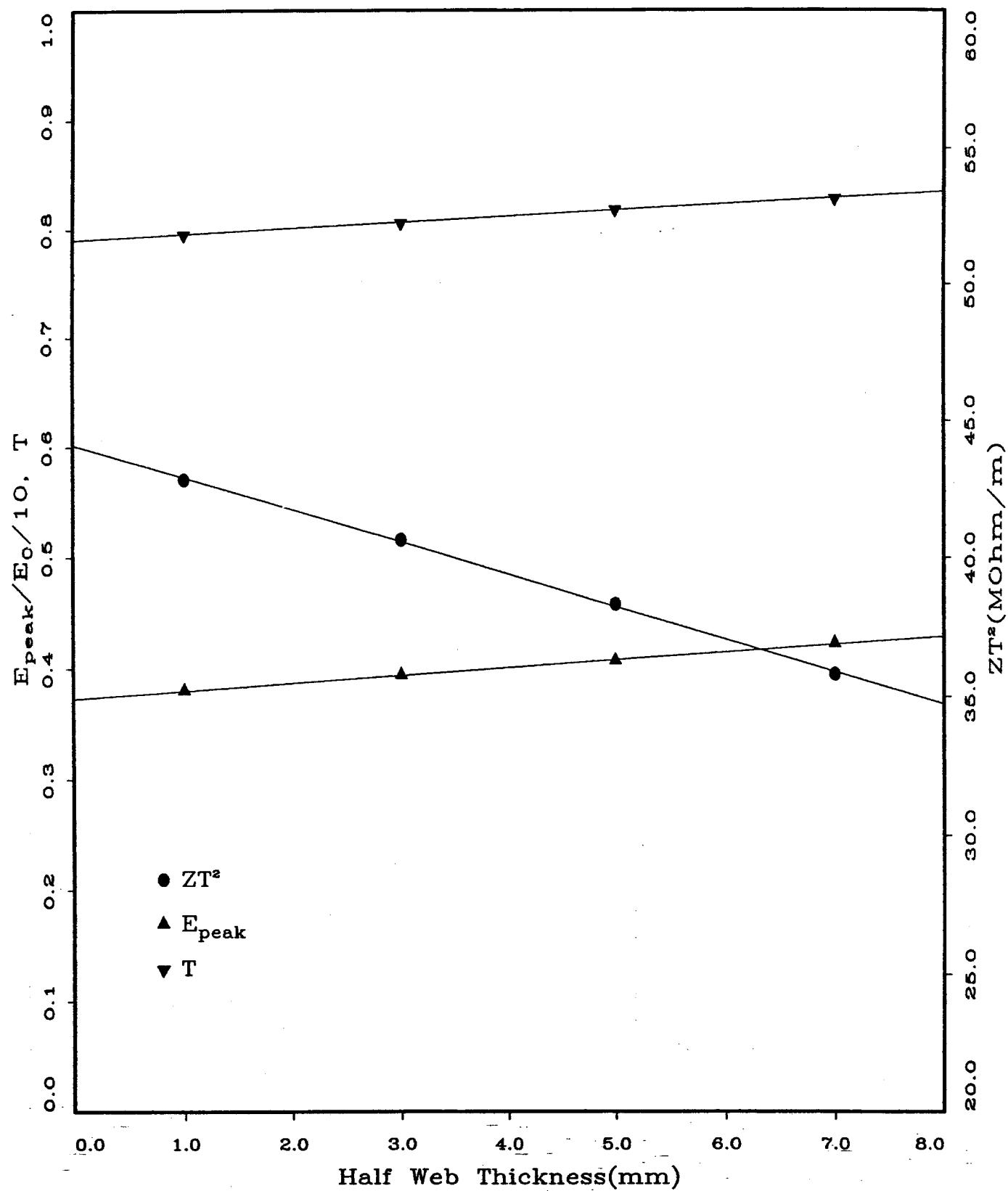
ZT^2 , E_{peak} and T vs. Radius at 393.9Mev



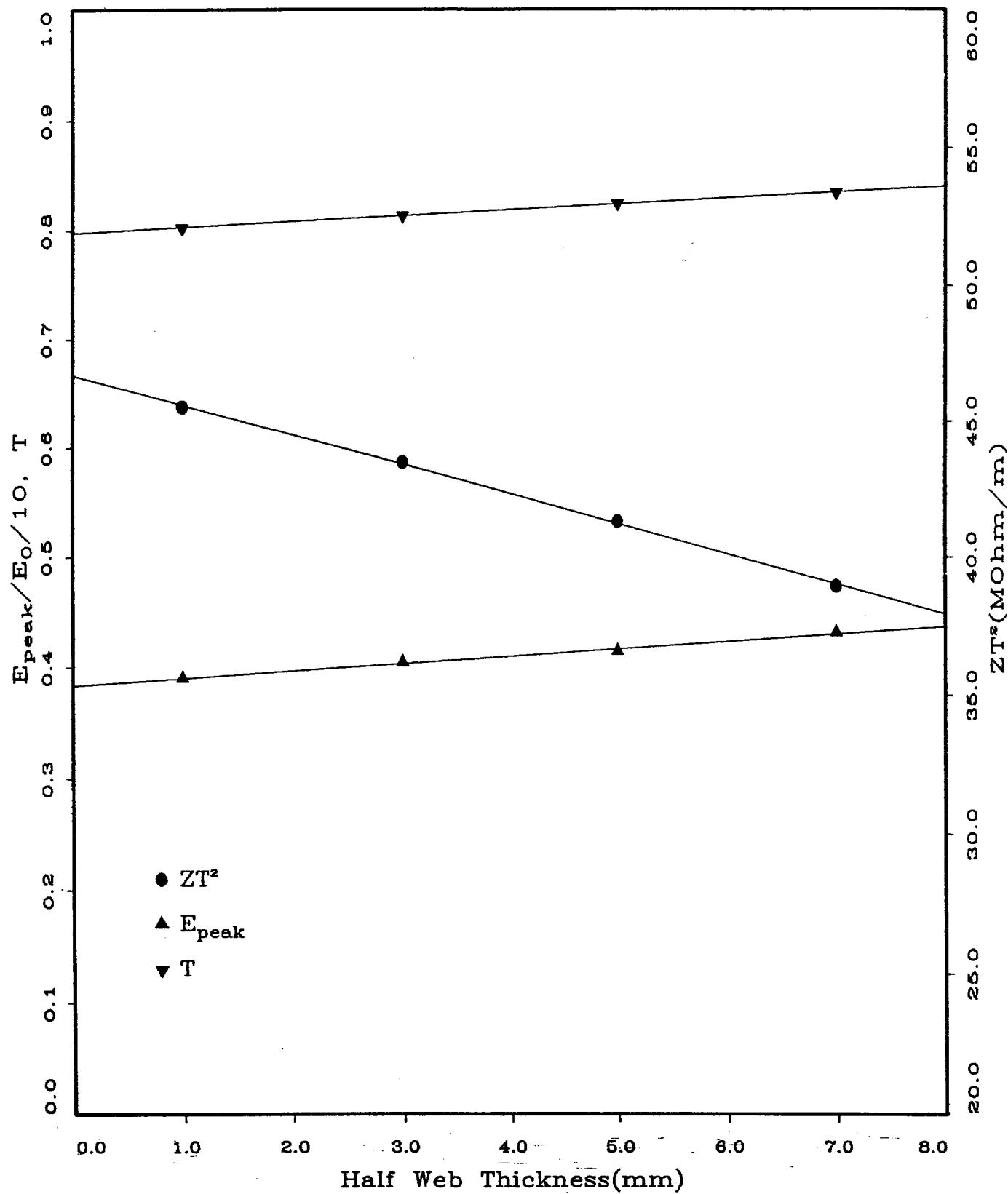
Appendix 2

ZT^2 , E_{peak} and T vs. Web Thickness at the eight energies listed in Table 1.
All other cavity dimensions are the same as the Reference Design.

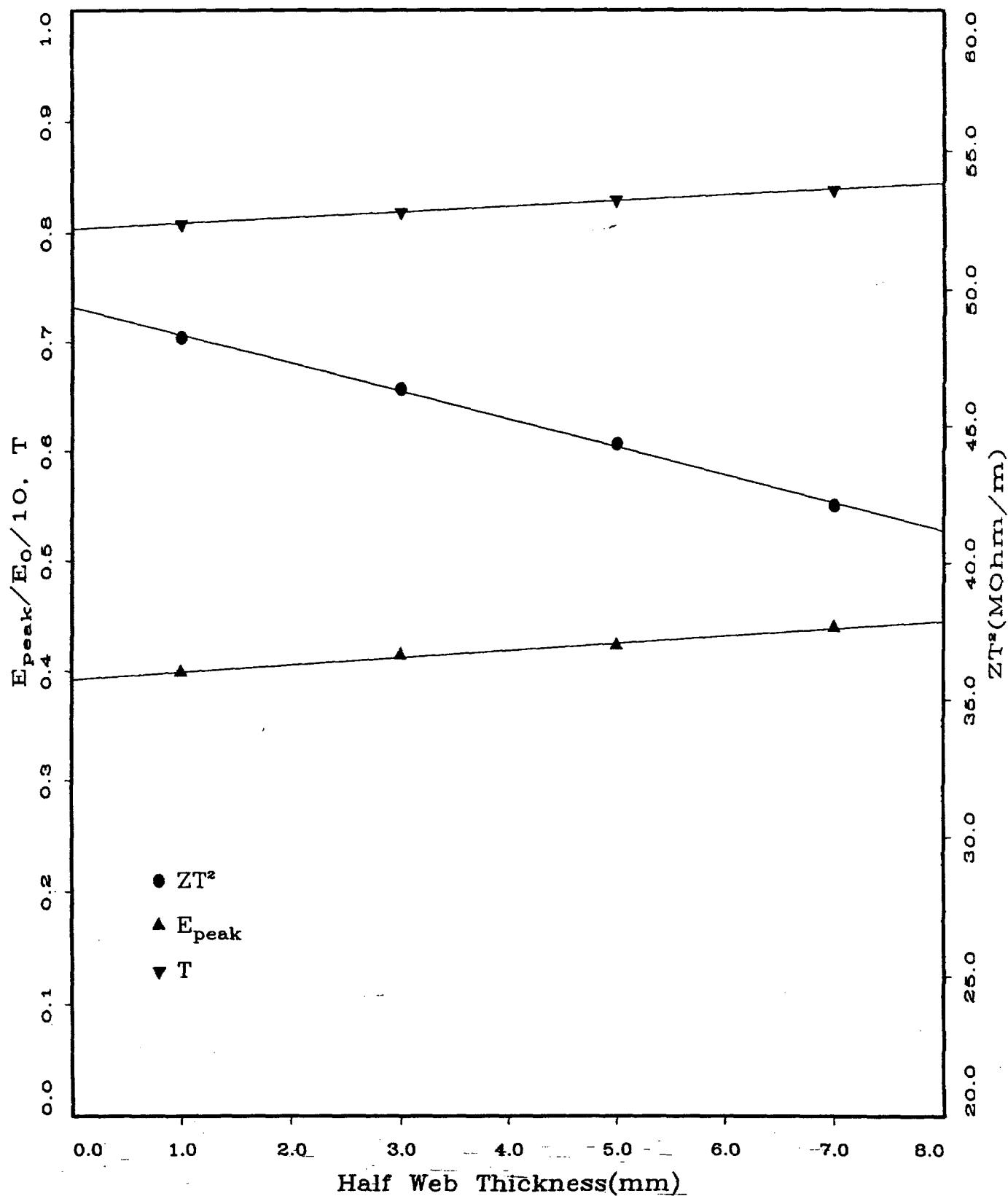
ZT^2 , E_{peak} and T vs. Wb-thck at 116.54Mev



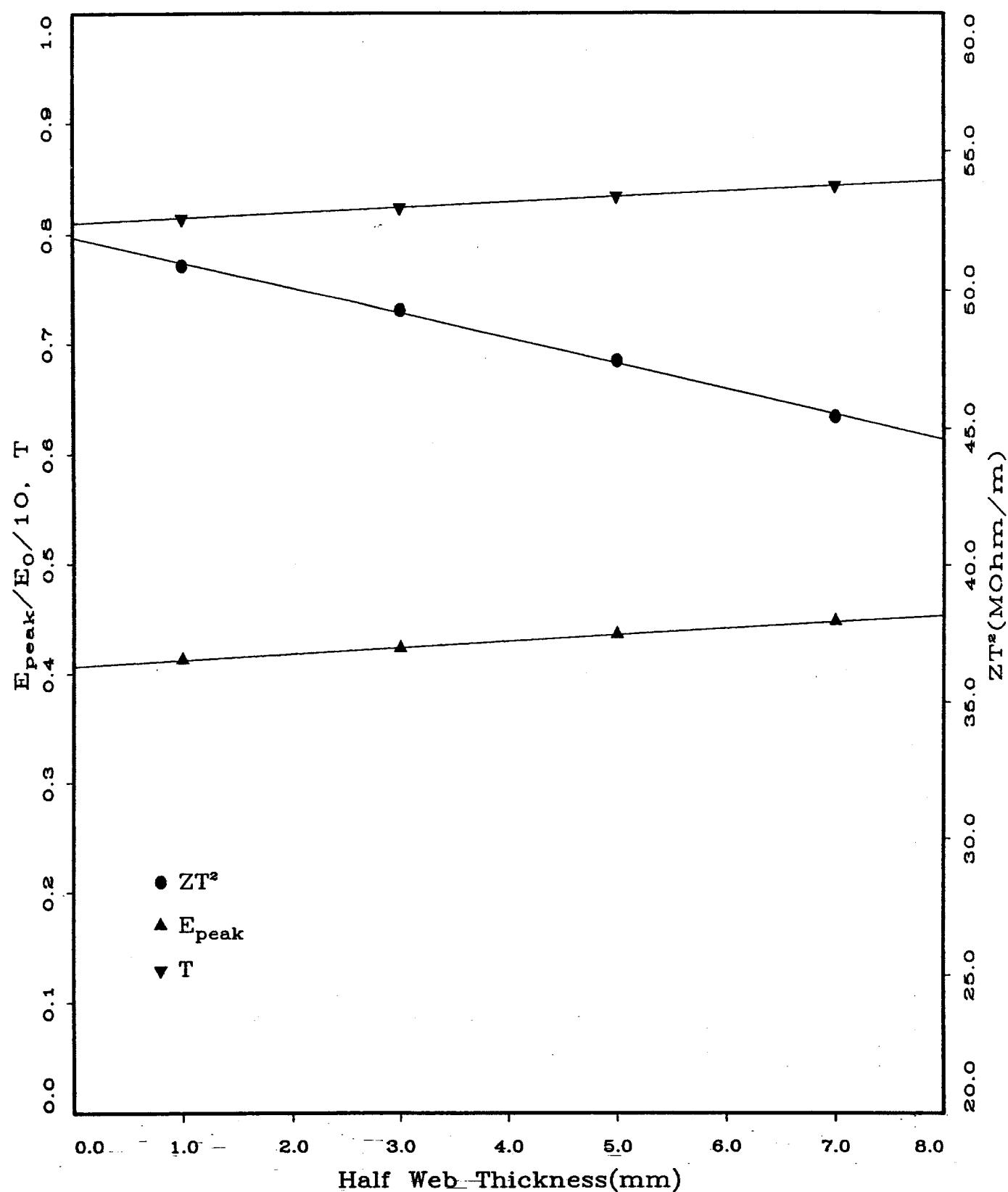
ZT^2 , E_{peak} and T vs. Wb-thck at 137.9Mev



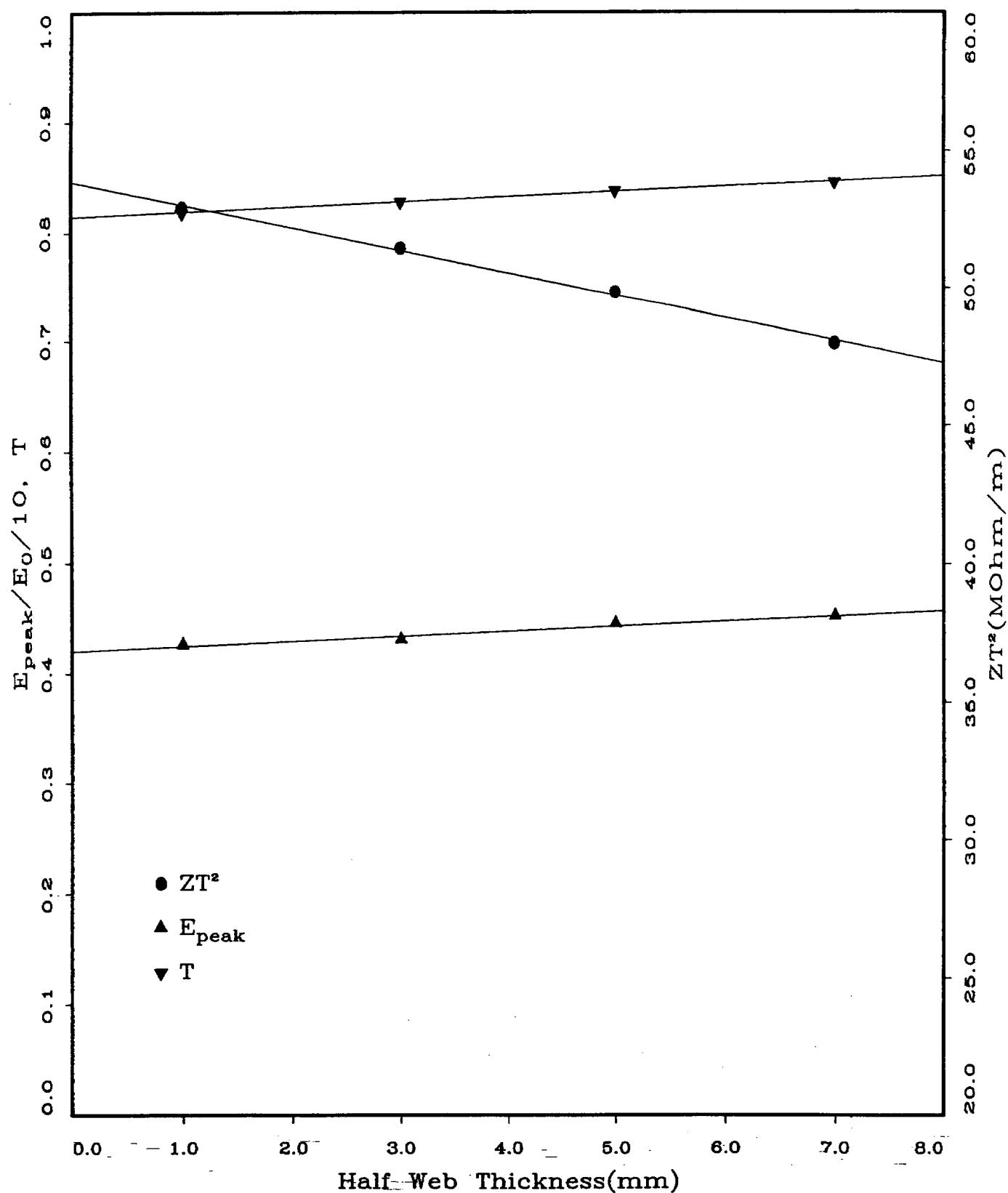
ZT^2 , E_{peak} and T vs. Wb-thck at 165.1Mev



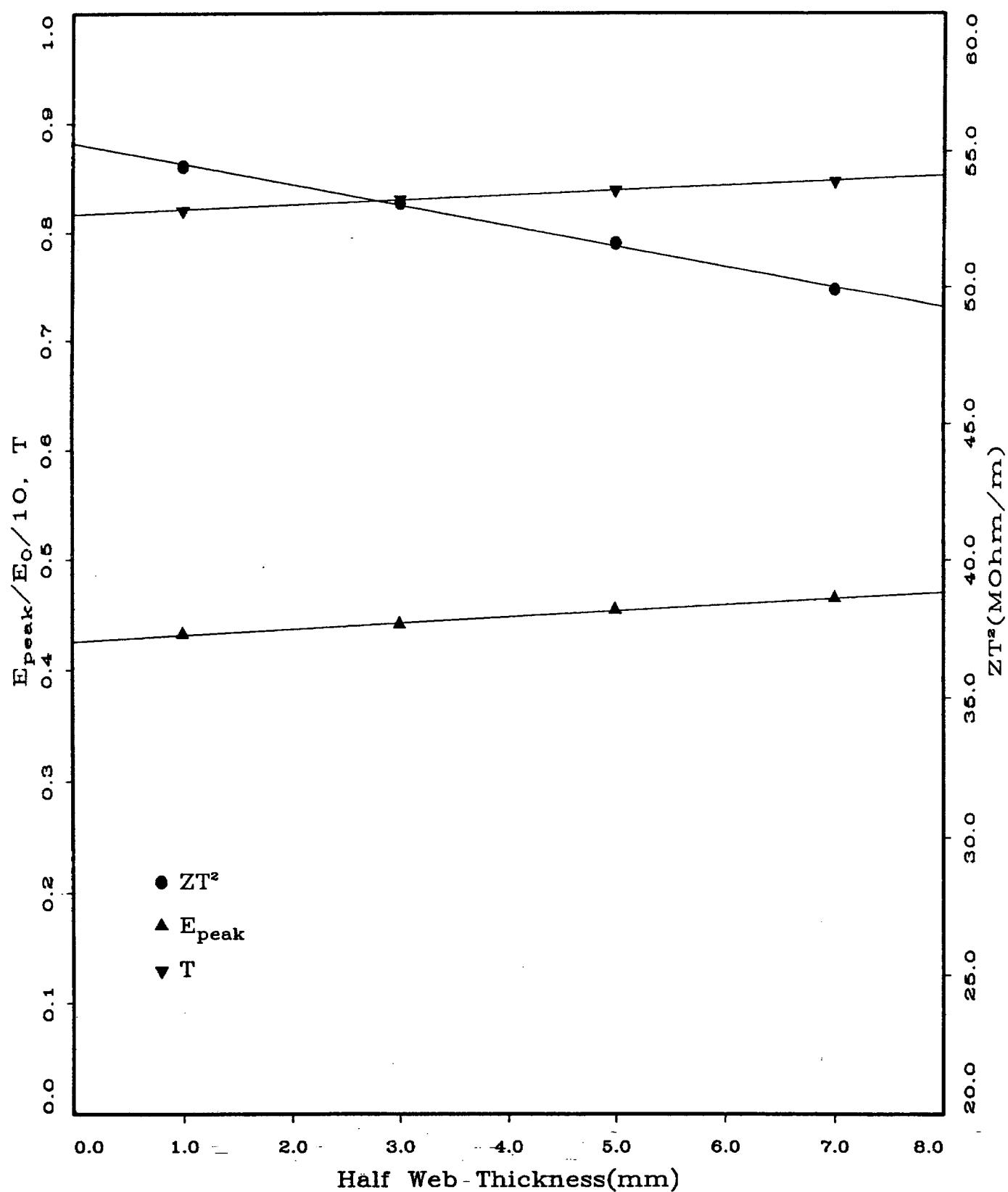
ZT^2 , E_{peak} and T vs. Wb-thck at 203.4Mev



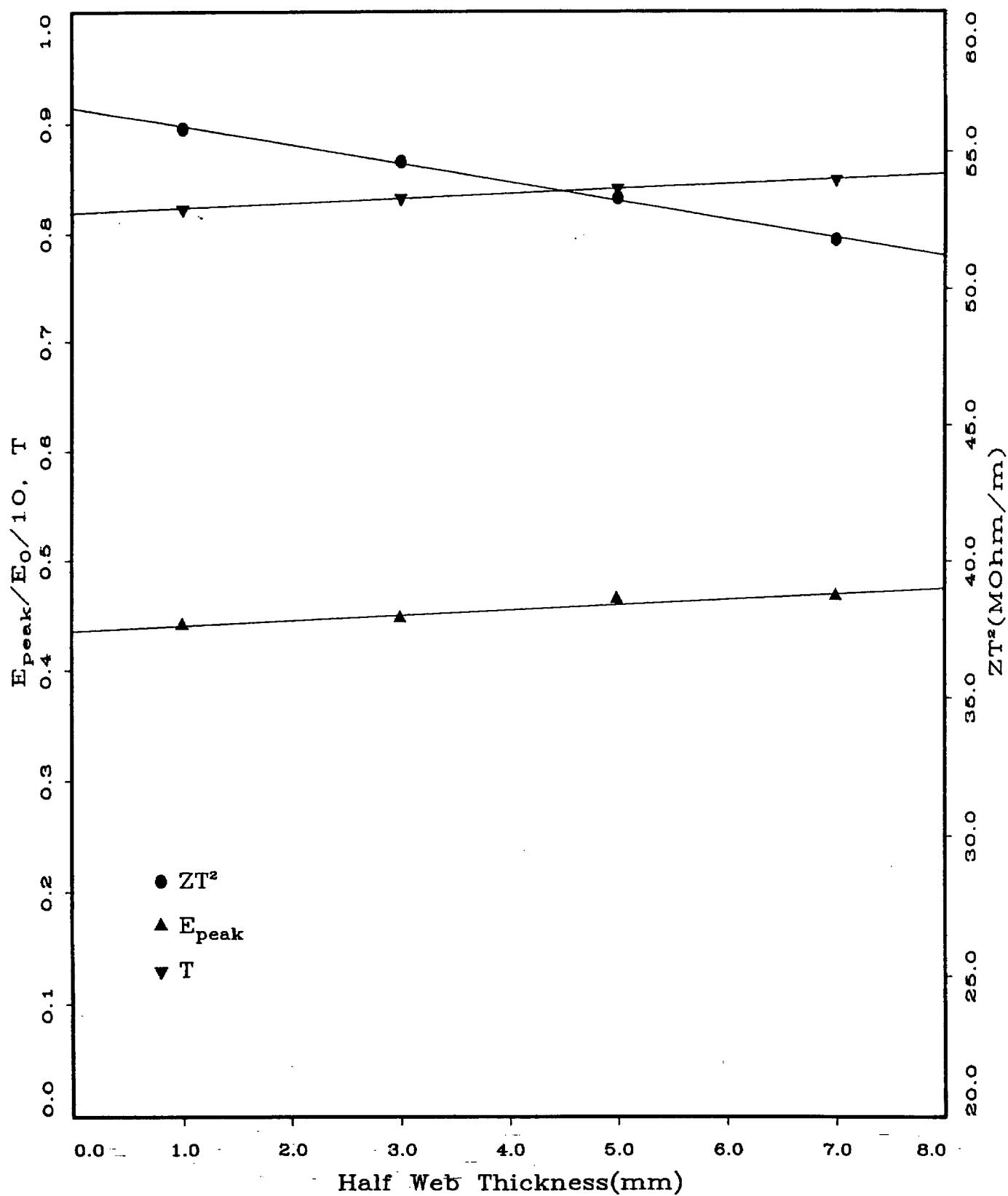
ZT^2 , E_{peak} and T vs. Wb-thck at 243.5Mev



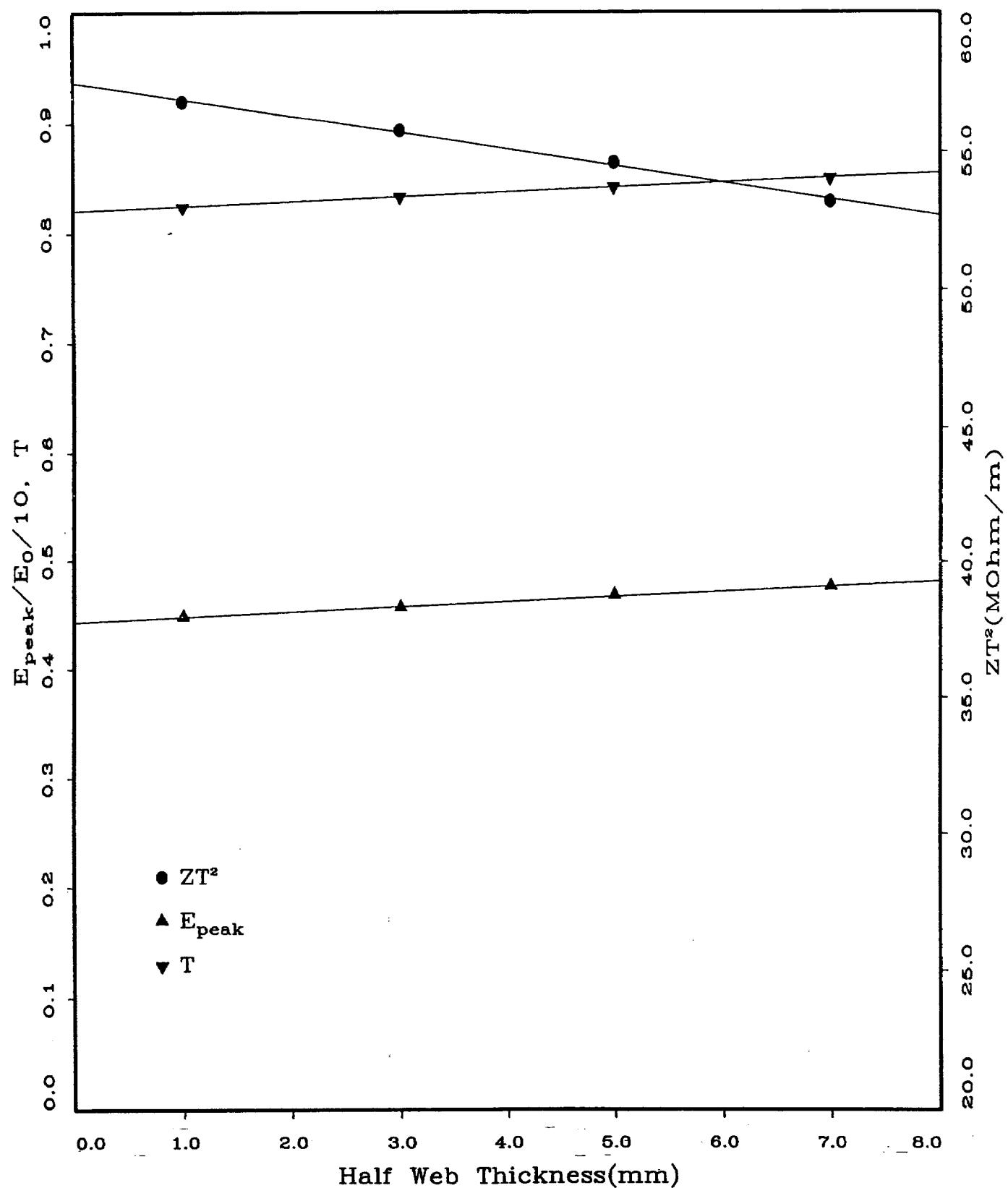
ZT^2 , E_{peak} and T vs. Wb-thck at 285.1Mev



ZT^2 , E_{peak} and T vs. Wb-thck at 338.7Mev



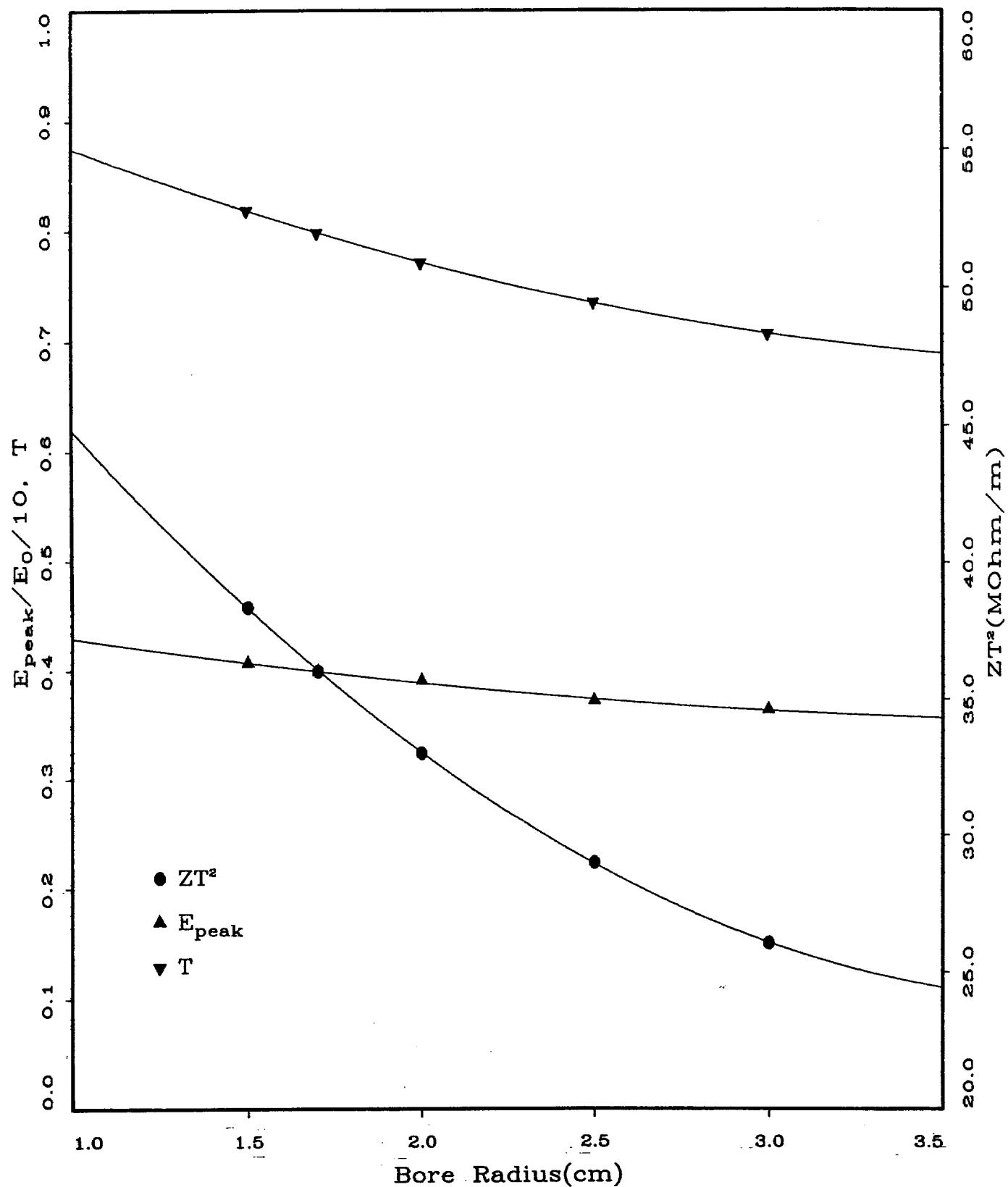
ZT^2 , E_{peak} and T vs. Wb-thck at 393.9Mev



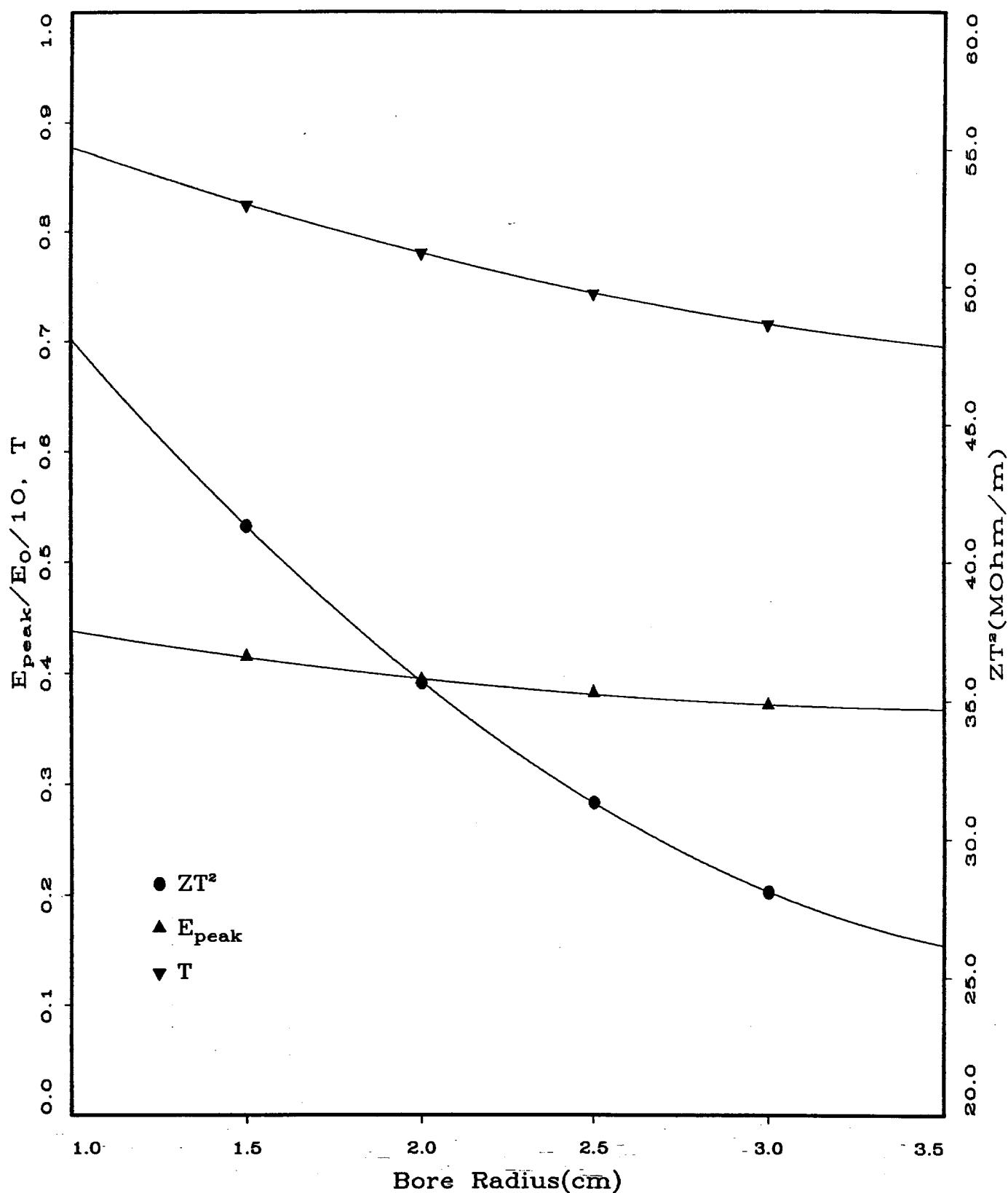
Appendix 3

ZT^2 , E_{peak} and T vs. Bore Radius at the eight energies listed in Table 1. All other cavity dimensions are the same as the Reference Design.

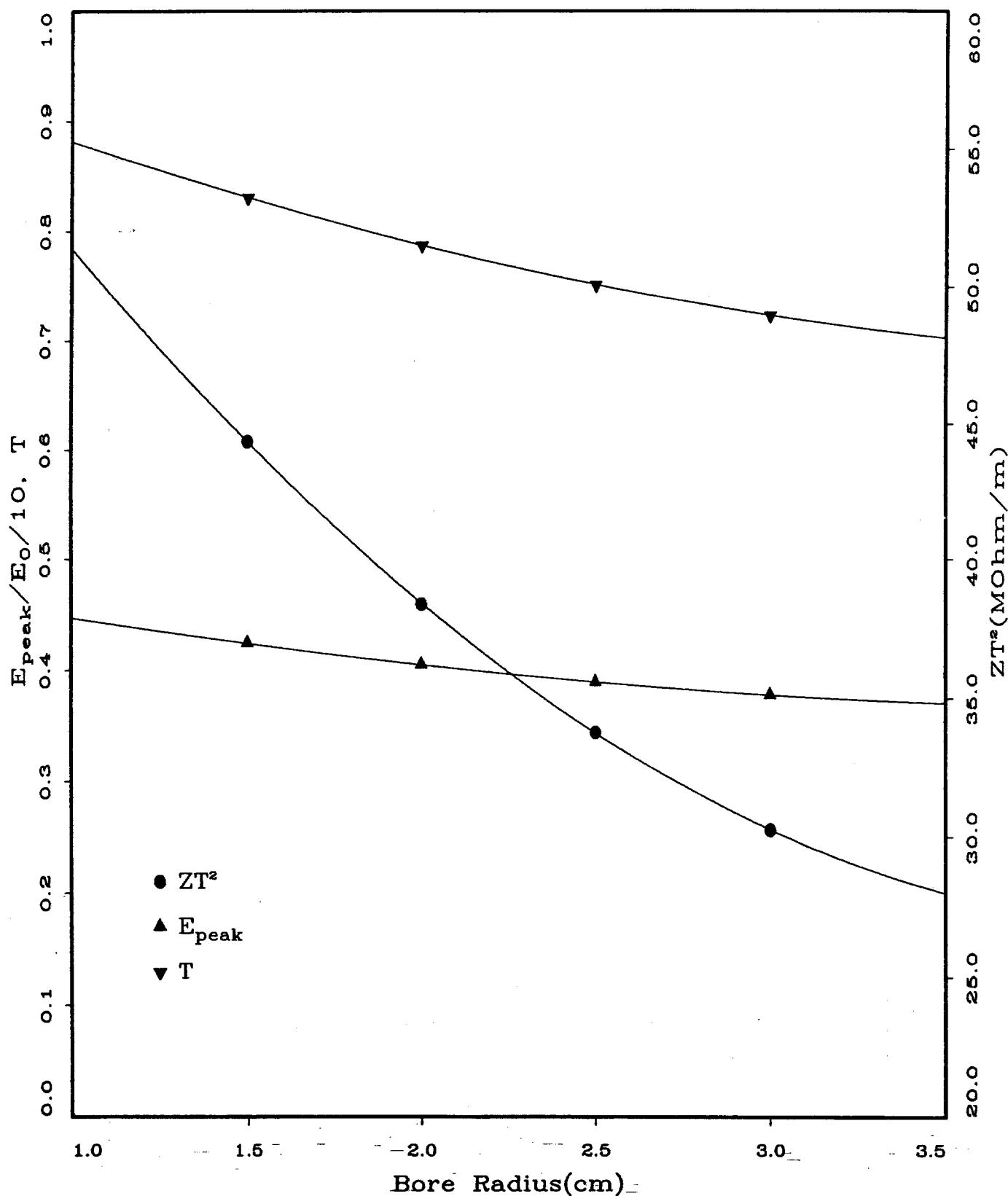
ZT², E_{peak} and T vs. Bore Radius at 116.54Mev



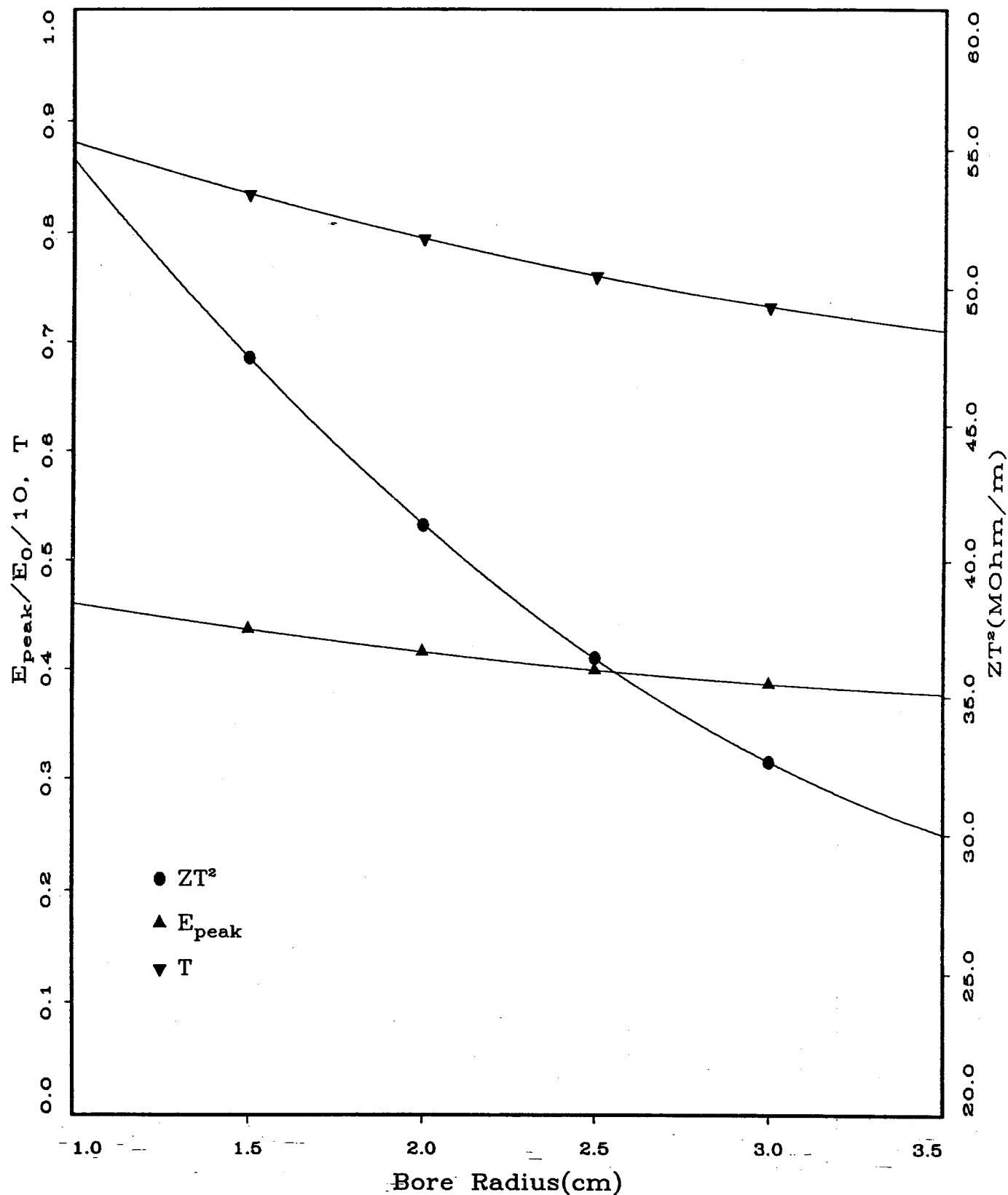
ZT^2 , E_{peak} and T vs. Bore Radius at 137.9Mev



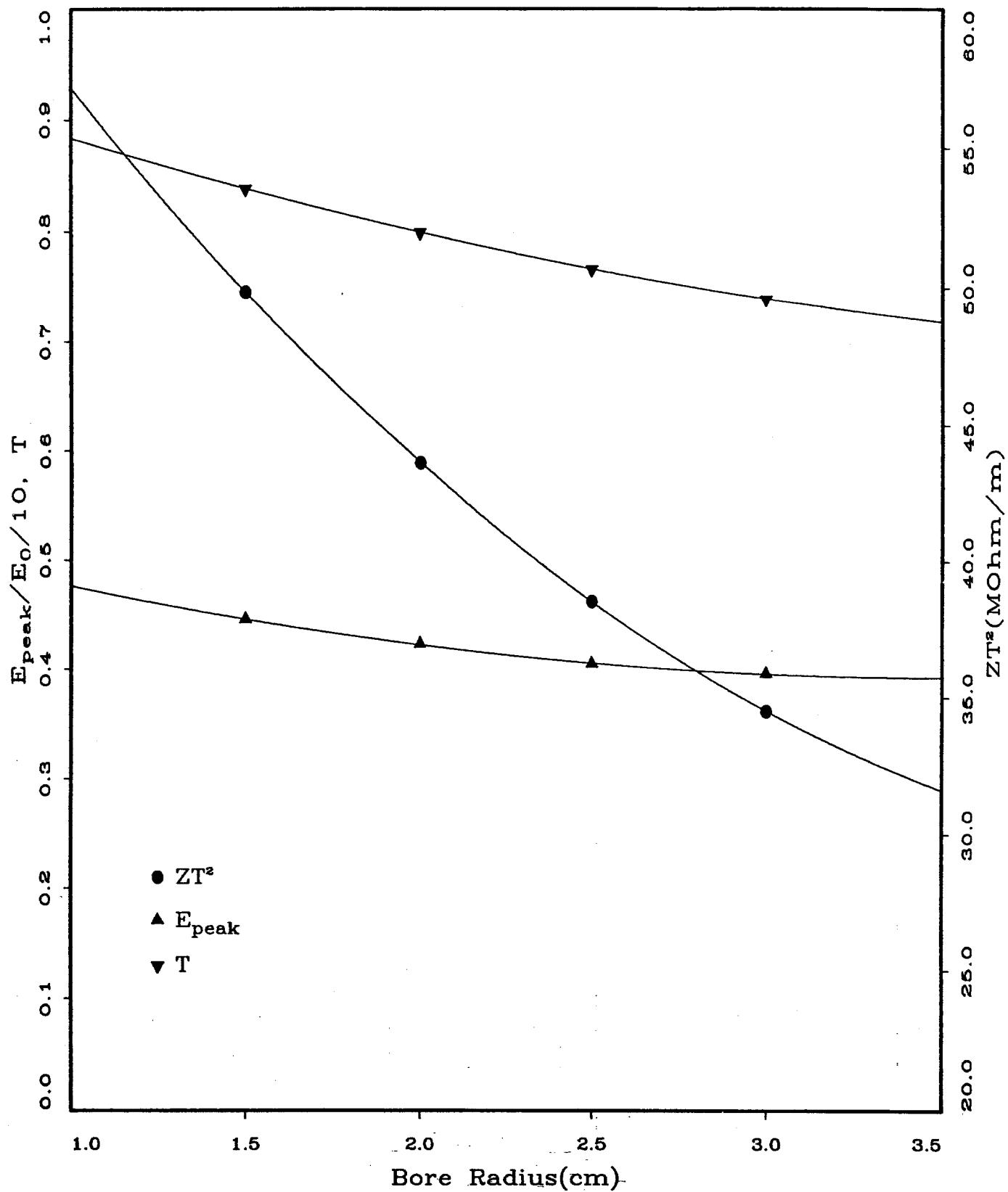
ZT², E_{peak} and T vs. Bore Radius at 165.1Mev



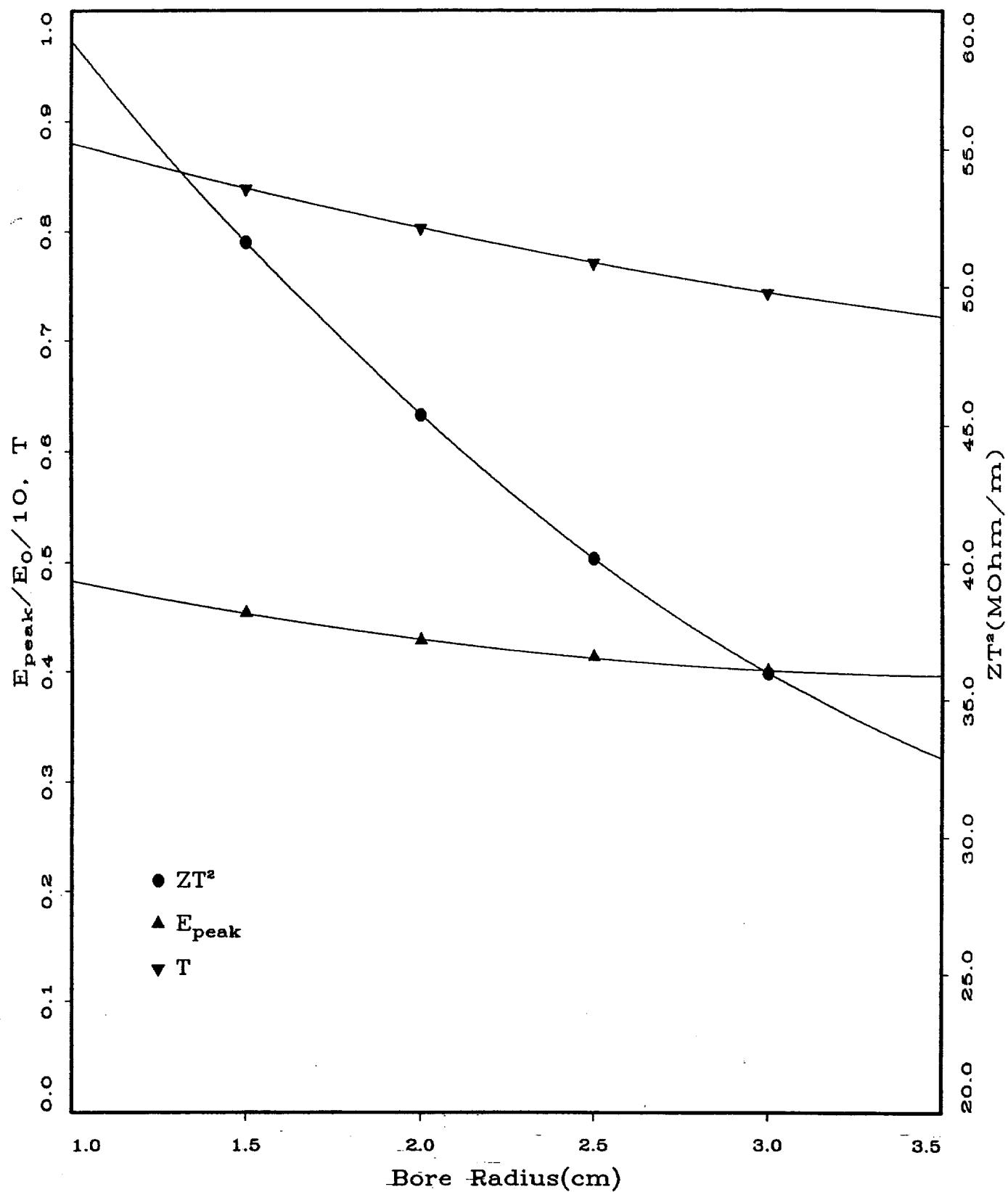
ZT^2 , E_{peak} and T vs. Bore Radius at 203.4Mev



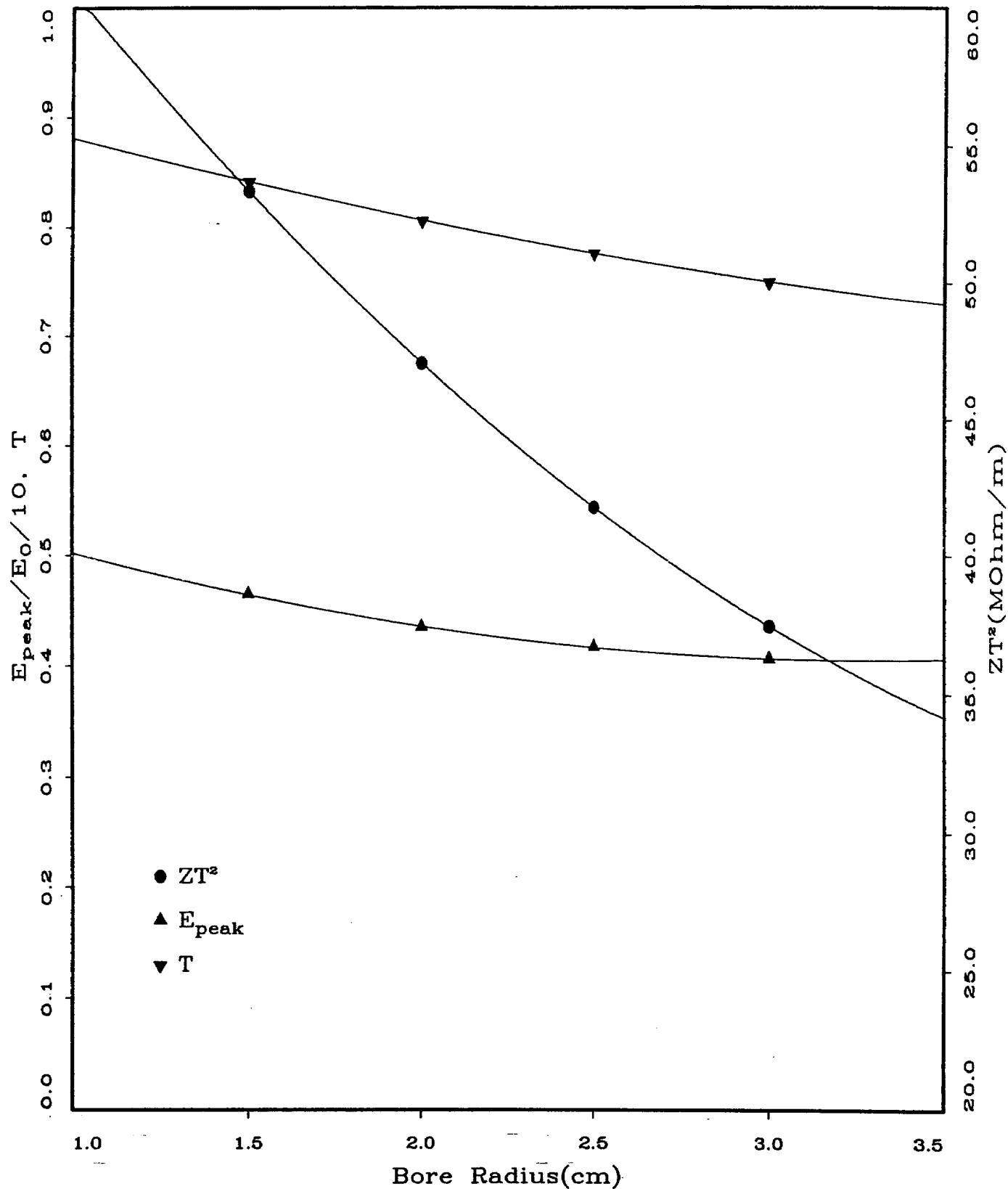
ZT^2 , E_{peak} and T vs. Bore Radius at 243.5Mev



ZT², E_{peak} and T vs. Bore Radius at 285.1Mev



ZT^2 , E_{peak} and T vs. Bore Radius at 338.7Mev



ZT², E_{peak} and T vs. Bore Radius at 393.9Mev

